COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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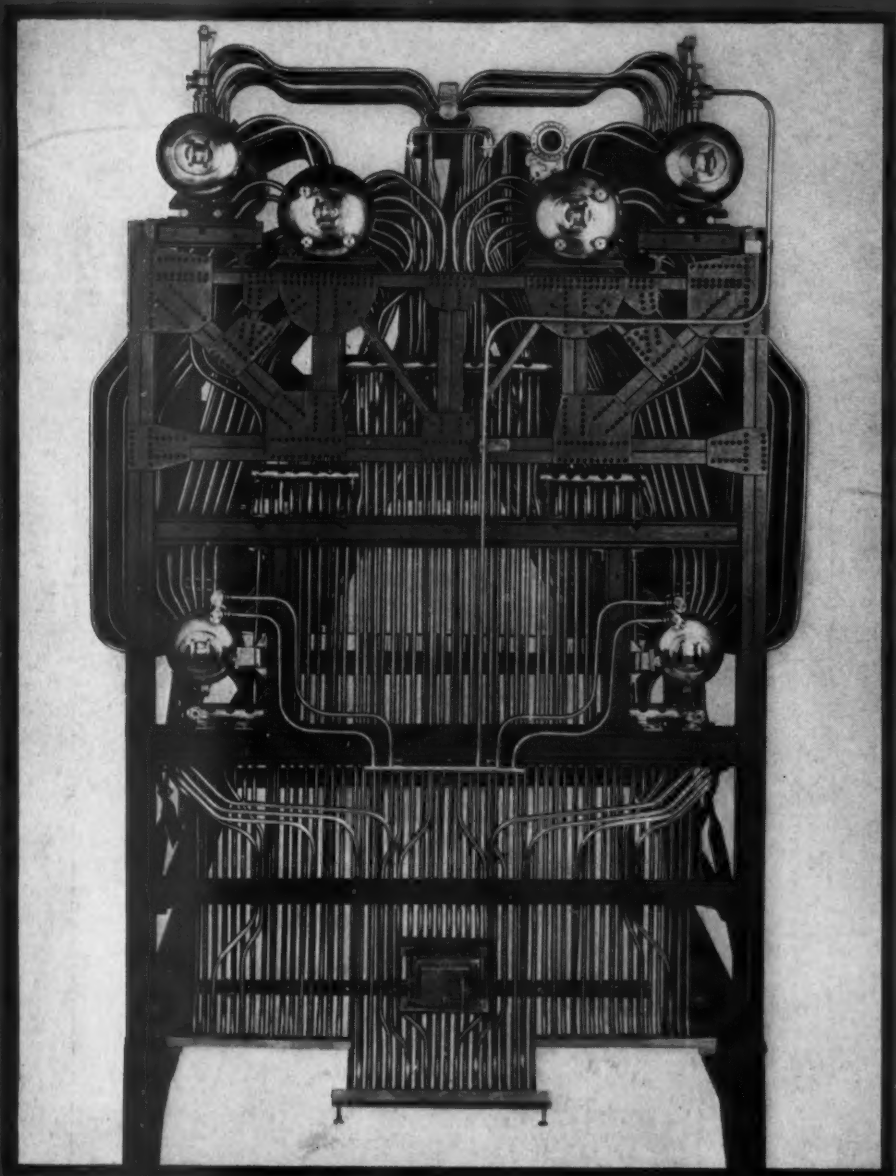

Model of Conners Creek Boilers; see page 36

Test of Unit No. 5 at Rouge Plant of the Ford Motor Company

Combustion Instruments and Control at Hell Gate

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FOR APRIL 1937

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ALFRED D. BLAKE, *Editor*

THOMAS E. HANLEY, *Circulation Manager*

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EDITORIAL

Steel Deliveries

According to business reports in the daily press, steel production at the end of March had attained a new high record, exceeding that of June 1929. Production of steel ingots is up to ninety per cent of mill capacity and current bookings in excess of shipments have pushed back deliveries by an average of three months. Deliveries on plates are also considerably delayed.

This situation obtains despite price advances made necessary by recent wage adjustments and is rendered more acute by the shortening of the working week in the steel industry. Moreover, the demand for construction steel is still relatively small and the advent of a long anticipated building boom would likely incur further delay in deliveries.

The effect has already been felt in the field of power plant construction where delivery periods for materials entering into the fabrication of equipment are, in many cases, about twice those current a few months ago. It is this aspect of the situation, rather than lack of production capacity among the equipment manufacturers, that must be taken into consideration by those planning extensions to meet anticipated power demands in the near future.

Heat Balance Tests

Tests of Unit No. 5 at the Rouge Plant of the Ford Motor Company, as reported in this issue, emphasize the necessity of employing the heat balance method of determining the performance of large modern steam-generating units. With boilers of relatively small capacity and a simple station heat cycle it is both possible and satisfactory to weigh the coal and feedwater and measure the steam output. In fact, this method of conducting a weighed test was carried out last year on one of the comparatively large units at the Federal Central Heating Plant in Washington. But here, although large tanks and other costly equipment were required, the problem was not complicated by a regenerative system of feedwater heating to preclude weighing in open tanks.

If a test extends over a sufficient period there is no insurmountable difficulty in determining, with reasonable accuracy, the weight of coal fired, but to weigh over a million pounds of feedwater per hour in a closed cycle at high temperature, with turbine stage bleeding employed, is quite another problem.

In the heat balance method the losses, rather than the heat input and output, are measured and by deducting these the efficiency is arrived at. With proper precautions practically all of the losses can be measured accurately and those which cannot be so measured are of small magnitude. In fact, the errors are likely to be no greater than those involved in conducting a weighed test, as has been demonstrated in cases where both methods have been employed. Moreover, the saving in expense and avoidance of interference with regular plant operation are vital factors.

Because of these considerations the heat balance test for large units is now becoming generally accepted and at the A. S. M. E. Annual Meeting last December the matter was referred to a sub-committee of the Power Test Codes Committee, which now has it under consideration.

Molybdenum as a Catalyst

Molybdenum has become an important factor in imparting desired physical characteristics to alloy steels used in power plant construction, but the suggestion of its introduction into the furnace, along with the coal, to bring about certain beneficial effects would at first seem incredulous because of its cost. Nevertheless, experiments are now being conducted to this end and may achieve the desired results at nominal cost.

Many an old-time engineer was in the habit of employing oyster shells to overcome slagging troubles in his boiler, and the action of salt, under certain conditions, as an inhibitor of soot has long been recognized. It would appear then, from investigations to date, that the molybdenum acts as a catalyst which affects the character of the slag formed on the tubes surrounding the furnace.

The molybdenum is applied to the coal in the form of powdered molybdenum sulphide, sprayed on with oil. From one to two ounces of the powder and about a pint of oil are required per ton of coal. As the development proceeds it is likely that the method of application and the quantity required may undergo modification.

Present indications are that the treatment has little effect on fuel bed clinkers, but in at least one case it was most effective in ridding the furnace of a pulverized-coal-fired boiler of an accumulation of slag on the tubes and side walls. This treatment is now being tried out in several large boiler plants, both stoker and pulverized-coal fired, burning coals of different characteristics. However, conclusive data are not yet available.

Whatever merit it may possess, its use will not justify the employment of improper furnace designs; but even though it may prove to have only limited application, it may be the means of relieving certain existing boilers of acute slagging troubles.

TEST OF UNIT NO. 5 AT Ford Motor Company

By W. W. DULMAGE, Superintendent of Power
FORD MOTOR COMPANY, DETROIT

This plant is not only the largest industrial power plant in the world but has the greatest capacity in high-pressure steam. The latest steam-generating unit, which has now been in service over eight months, is the first of large capacity to operate regularly at a steam temperature over 900 F. It has developed over a million pounds of steam per hour at 1340 lb pressure and a nearly constant steam temperature of 910 F. The efficiency at rated capacity was 87.12 per cent. A review of the progressive steps in the modernization of this plant is also given.

IN JULY of 1936 the Ford Motor Company put into operation a new addition to its high-pressure installation at power plant No. 1, Dearborn, Michigan. This additional equipment consists of a steam-generating unit having a maximum rated capacity of 900,000 lb of steam per hour, at 1350 lb pressure and 910 F total temperature, one condensing non-reheat turbine-generator of 110,000 kw capacity, and one 15,000-kw turbine-generator exhausting at 250 lb pressure to evaporators which produce steam for factory use from treated make-up water.

During the first few months of operation various minor adjustments were made on this equipment to bring its operation in line with the guarantees. Last January and February complete tests were made and the equipment was found to conform to the guarantees in every respect. This installation has the distinction of being the first of large capacity to go into service with steam at a temperature over 900 F, the steam temperature being high enough to permit complete expansion to condenser vacuum without reheating.

The first installation of high-pressure equipment at this plant was completed in July 1931. It consisted of two steam-generating units, each of 700,000-lb per hr capacity, and one 110,000-kw turbine-generator. The steam was generated at 1350 lb pressure, and 750 F total temperature, and was expanded in the high-pressure turbine to about 85 lb pressure, reheated with high-pressure steam to 560 F in steam reheaters located at the turbine and then expanded in the low-pressure turbine to condenser vacuum. This first high-pressure equipment was described in the November 1932 issue of COMBUSTION.

The principal reasons for adopting 910 F total steam temperature were to avoid the use of steam reheaters and to obtain high thermal efficiency in power generation. Elimination of steam reheaters greatly simplifies the design and operation of the plant. The new high-pressure equipment can produce a kilowatt-hour with a heat rate appreciably under 11,000 Btu.

The River Rouge plant of the Ford Motor Company has the distinction of being not only the largest industrial plant in the world, but also the plant with the greatest power capacity generated by high-pressure steam. Since its initial construction in 1920 the steam-generating equipment has been consistently and progressively enlarged and revamped to keep it in the lead of current practice. The plant was one of the pioneers in large units and in pulverized-coal firing, and it has adhered to this practice throughout intervening years.

Original Installation and Progressive Modernization

The original installation in 1920 consisted of four double-set, bent-tube boilers designed for 200,000 lb of steam per hour at 240 lb pressure, 650 F steam temperature, to supply four turbine-generators each of

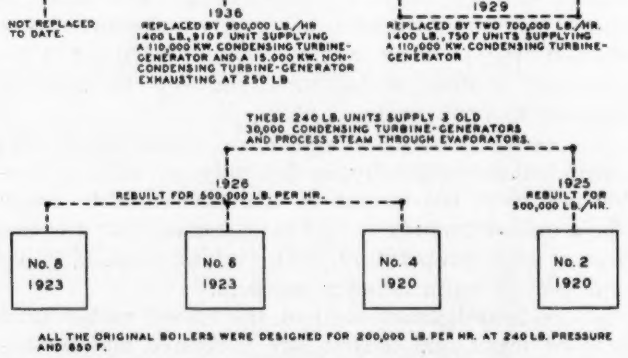
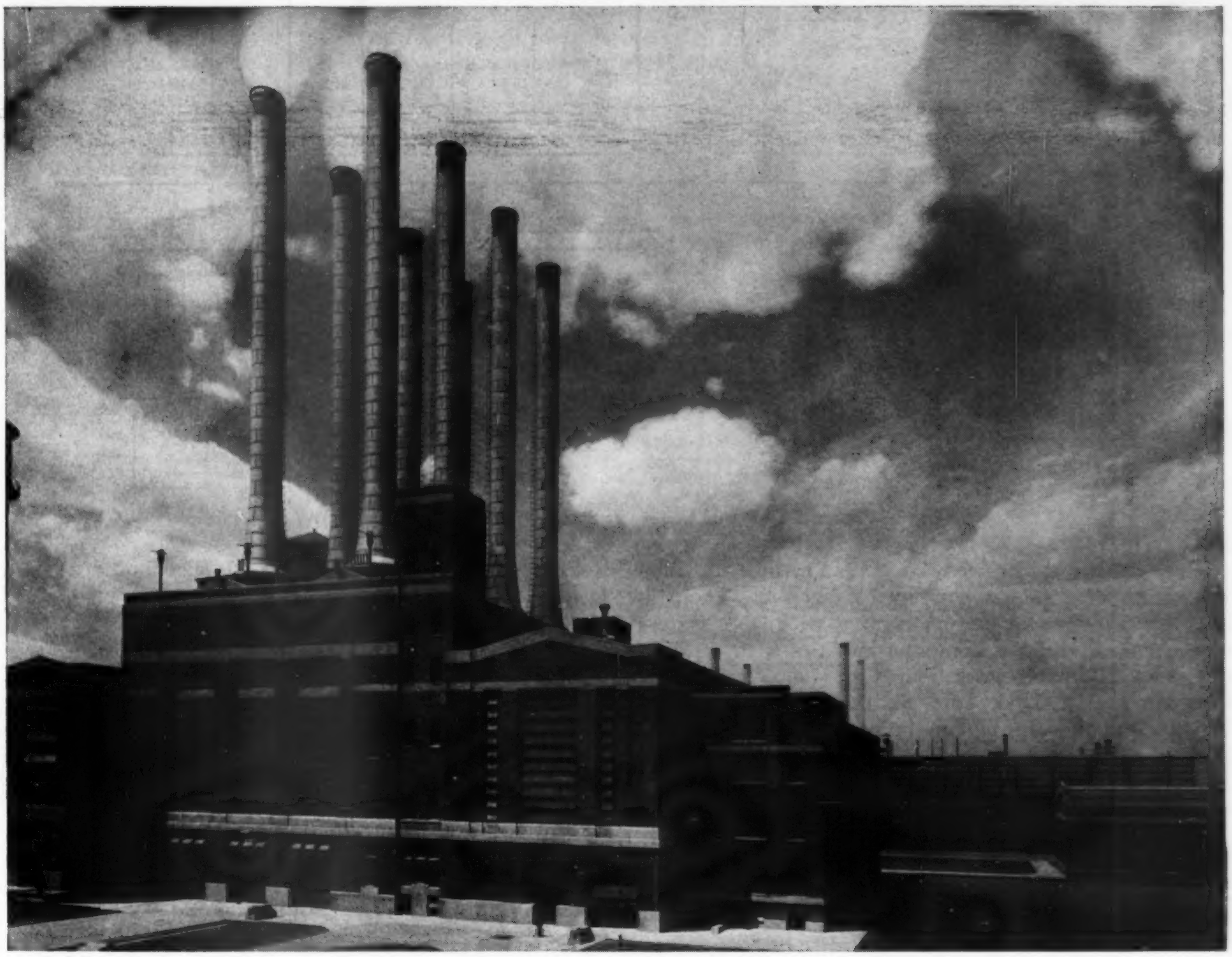


Fig. 1—Diagram of progressive modernization of Rouge boiler plant

ROUGE PLANT OF THE



30,000 kw capacity. Four similar units were added in 1923. All these boilers were equipped with a storage system of pulverized-coal firing.

The rapidly increasing steam and power demands at the Rouge Works soon indicated the necessity for still greater capacity and, in order to attain this within the same boiler-room floor space, the No. 2 unit, one of the original boilers, was rebuilt in 1925 to more than double its output. This was soon followed by similar rebuilding of units Nos. 4, 6 and 8. The reconstruction involved the application of water walls, plate-type air heaters and additional burners. The application of water walls was unique in that they were installed so as to form a circulation circuit separate from that of the boiler proper and the steam was superheated in individual radiant superheaters. In 1929 units Nos. 1 and 3, two of the original units, then only nine years old, were replaced by the two 750,000-lb per hr, 1400-lb, 750-F units of the same general type. The latest unit of 900,00-lb per hr rated capacity replaced, in the same floor space, the old No. 5 unit, one of the 200,000-lb per hr units installed in 1923. Thus the present boiler plant of 4,500,000-lb per hr rated capacity contains three 1400-lb units, four rebuilt 240-lb units and one of the original 240-lb units as installed in 1923. All of the boilers are of the CE double-set, bent-tube design, fired with pulverized coal from a storage system, which is supplemented by blast-furnace and coke-oven gas when available. The diagram, Fig. 1, represents graphically the boiler-room modernization program as carried out at the Rouge plant over the past 15 years and Fig. 2 shows the present arrangement of the power plant.

In the turbine room there are two 110,000-kw high-pressure, G-E vertical-compound, condensing turbine-generators, the first taking steam at 1215 lb and 725 F and the second at this pressure and 900 F at the turbine throttle; a 15,000-kw, non-condensing turbine-generator and three of the earlier 30,000-kw, 250-lb turbine-generators, built by the Ford Motor Company, make a total of 325,000 kw installed capacity.

In addition to the main power plant there is a second smaller power plant at the Rouge Works containing

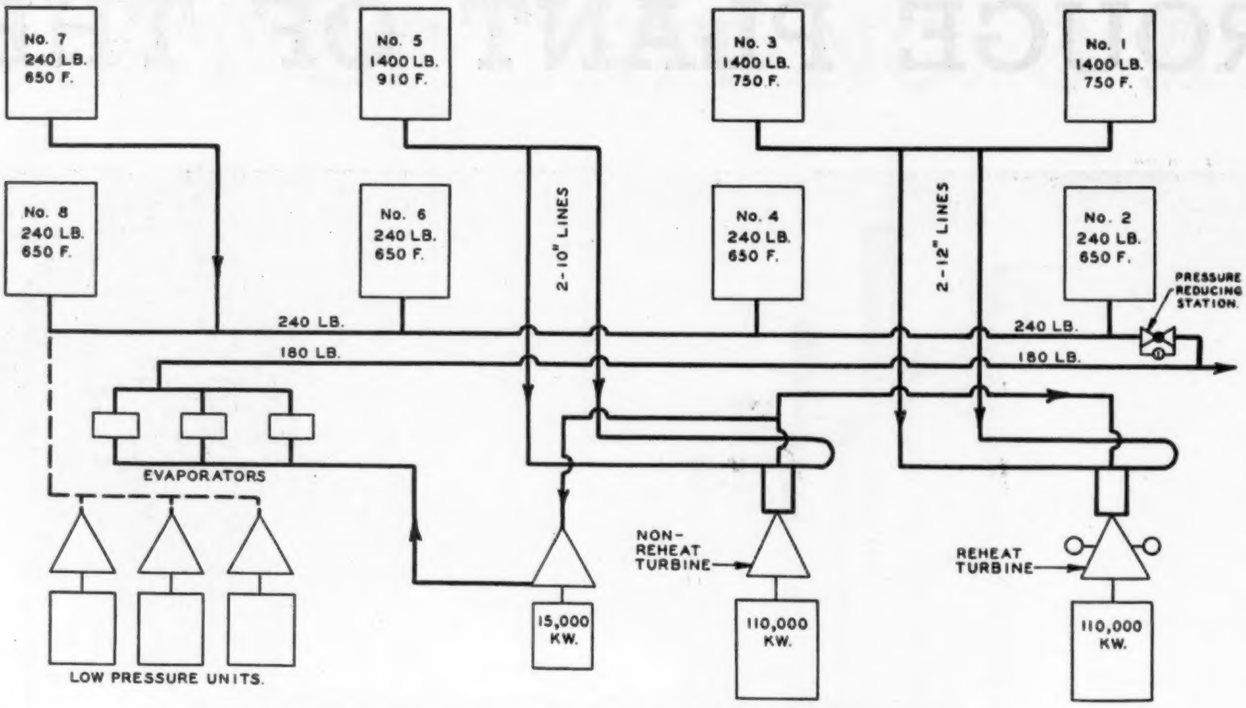


Fig. 2—Present layout of boilers and turbines at the Rouge plant

twelve 400-hp stoker-fired boilers and three turbine-generators of 7500 kw combined capacity. There is also a 60,000-kw tie line connecting with the system of the Detroit Edison Company and ties with the Lincoln and Highland Park plants of the Ford Motor Company. The peak load at the Rouge Works is 160,000 kw and the maximum process steam demand approximates 740,000 lb per hr. Extensions of the steel and the glass plants were largely responsible for the most recent increase in capacity.

Details of Latest Steam-Generating Unit

As shown in the cross-section, Fig. 3, the new steam-generating unit consists of a bent-tube, double-set boiler having five drums, two superheaters, two fin-tube economizers and twin plate-type air heaters. The furnace is completely water cooled, is of the dry-bottom type and tangentially fired by four sets of five burners, one set located in each of the four corners. The bottom burner of each set is arranged for burning blast-furnace gas and the top burner coke-oven gas. The middle three burners are for burning pulverized coal which is the main fuel of the plant. The gas fuel is burned principally when the unit is being put into operation, or over the week-end when there is no other use for the gaseous fuel. The gas can be burned separately or in combination with coal.

The air is forced through the air heaters by four turbo-vane blowers driven by two-speed motors at 1200 and 1800 rpm synchronous speed. The capacity of each blower is 70,000 cfm at 100 F temperature and 10.25 in. of water pressure at the higher speed.

The draft is provided by two turbo-vane induced-draft fans driven by two-speed motors at 885 and 588 rpm. The capacity of each induced-draft fan is 260,000 cfm at 367 F and 10.2 in. of water suction at the higher speed. The lower speed is good up to nearly 800,000 lb of steam capacity. The higher speed is used only for peak load conditions.

The heating surface of the unit is distributed as follows:

Boiler	30,000 sq ft
Water walls	9,500 sq ft
Superheater	21,940 sq ft
Economizer	25,300 sq ft
Air heater	86,000 sq ft

The furnace has a horizontal section of 25.8 by 32 ft and a volume of 30,000 cu ft and is designed for a heat release of 34,000 Btu per cu ft when the unit delivers 900,000 lb of steam per hr. It is completely water cooled, the sides being made up of 3-in. fin tubes on 5 $^1/_8$ in. centers and the bottom, which is of the dry-ash type, consists of plain tubes.

The unit has four boiler drums and one dry drum, the former being forged shells with welded-on heads. The two bottom drums are 40 in. diameter, 31 ft long and the shells are 5$^1/_4$ in. thick. The upper two drums are 48 in. diameter, 35$^1/_2$ ft long and the shells are 6$^1/_4$ in. thick. The dry drum is of welded shell and welded-on head construction, 40 in. diameter and 28 ft long with a shell thickness of 3$^{11}/_{16}$ in.

The superheater elements connect directly by rolled and welded joints to the dry drum with an intermediate screwed and welded union joint. The outlet end of the superheater elements is connected similarly by welded joints and screwed union to a 14-in. header. The welded joints make steam-tight connections and the screwed unions supply the mechanical strength. Beyond the stop valve the 14-in. header is divided into two 10-in. steam lines.

To prevent the temperature of superheated steam from going too high at high ratings, gas bypassing dampers are provided. These dampers are operated by four air cylinders controlled by a thermostat. However, the superheated steam temperature curve (see Fig. 5) becomes flat when the temperature of 918 F is reached at about 850,000-lb per hr steaming capacity. So far there has been no need of using the gas bypassing dampers.

The water-cooled furnace is connected into the boiler circulation by properly designed downcomers and steam risers.

Eastern Kentucky coal is burned, having an average of 6.7 per cent of ash, 1.30 per cent moisture and 0.54 per cent sulphur. Ash is removed from the bottom of the furnace by two screw conveyors having water-cooled shafts. This method of ash removal was developed on the low-pressure boilers and is also used on the first high-pressure boilers.

Four-stage feedwater heating is employed with steam extracted from the turbine at 7.4, 25, 86 and 225 lb absolute pressure. The feedwater enters the economizer at a temperature of 405 F and is heated to 480 F by the time it enters the boiler. It is deaerated in a deaerating heater.

This latest steam generating unit (No. 5) is connected also with the first high-pressure turbine-generator. This connection is shown in Fig. 2. The same cross-connection can be used to deliver steam from steam generating units Nos. 1 and 3 to the 15,000-kw turbine-generator exhausting at 250 lb pressure into the evaporators. The latter supply steam at 180 lb for the factory use

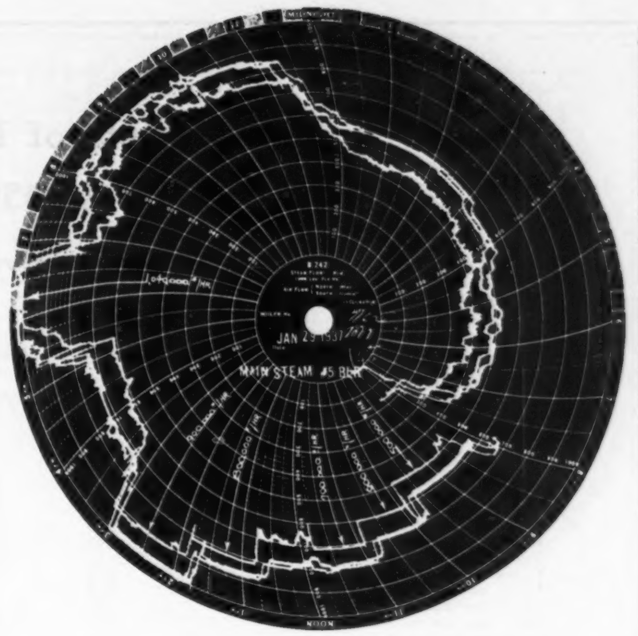


Fig. 4—Typical steam-flow-air-flow chart

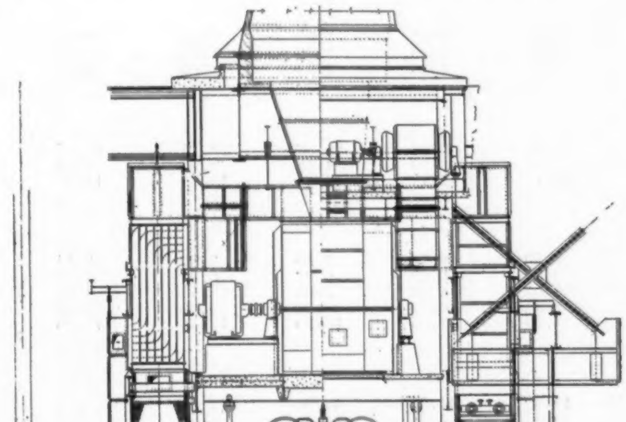


Fig. 3—Cross-section of steam-generating unit No. 5

from makeup water. The remainder of the steam required by the factory is generated in the low-pressure boilers at 240 lb pressure.

Performance of the Unit No. 5

This unit has been in service over eight months and considerable operating data have been accumulated. The table shows the results of a series of tests which extended over a period of several days. The results are also shown graphically in Figs. 5, 6 and 7.

The maximum guaranteed output of the unit was 900,000 lb per hr, but 1,020,000 lb of steam has been carried for an hour at a time without any sign of trouble either in the furnace or in the boiler. The steam-flow chart, Fig. 4, shows the range of ratings covered during turbine tests. This chart indicates the flexibility and response of the boiler.

Boiler Water Conditioning

Total boiler water concentrations are kept below 400 ppm. Sodium metaphosphate, $(NaPO_3)_6$, (also known under the trade names of Buromin and Hagan phosphate) is used by injection with feedwater to keep the phosphate content of the boiler water between 20 and 60 ppm. In a similar manner, caustic soda is injected into the boiler to control the alkalinity. The pH value is held at approximately 11 and no attempt is made to maintain the sulphate-carbonate ratios recommended by the A.S.M.E.

Bringing No. 5 Unit on the Line

The unit is equipped with coal, coke-oven gas and blast-furnace gas burners and these fuels may be burned individually or in combination. The lower row of coal burners is also equipped with coke-oven gas pilot lights for lighting the coal burners when blast-furnace gas is not available.

After filling the boiler to the normal water level, the valves between the boiler and the economizers are closed and a small quantity of water is circulated through the economizers. This is accomplished by operating

Tests of No. 5 Boiler
FORD MOTOR COMPANY
River Rouge

Number	3	1	2	4	5	6	7
Date	1/26/37	1/21/37	1/22/37	1/27/37	1/28/37	1/28/37	1/29/37
Duration—hr	6	6	6	6	2	2	3/4
Evaporation—lb per hr							
By steam flow meter	413,000	614,000	706,000	820,000	901,000	940,000	1,020,000
Temperatures—F							
Superheated steam	816	875	899	905	914	919	909
Water to economizer	347	358	367	393	403	409	400
Water to boiler	418	443	455	476	488	495	479
Furnace, ashpit	1915	2111	2127	2125	2156	2153	...
Furnace, burner level	2543	2698	2697	2707	2736	2729	...
Furnace, third floor	2613	2802	2816	2804	2825	2840	...
Gases leaving boiler	731	826	858	870	901	916	918
Gases leaving economizer	458	540	572	590	619	634	632
Gases leaving air heater	293	337	350	357	386	391	382
Air to air heater	92	104	100	90	103	106	96
Air from air heater	369	414	424	429	451	460	452
Dry bulb	98	...	108	99	108	111	...
Wet bulb	66	...	70	66	71	72	...
Primary air	369	414	424	429	451	460	452
Pressures—lb per sq in. gauge							
Boiler steam drum	1246	1263	1281	1315	1329	1351	1340
Superheater outlet below valve	1243	1243	1253	1260	1250	1255	1245
Feedwater to economizer	1528	1529	1533	1524	1674	1700	1700
Air pressures—in. of water							
Air heater inlet	3.27	4.4	5.08	6.98	8.30	9.75	11.45
Secondary air	2.15	2.15	2.13	3.30	4.18	5.45	6.25
Primary air	10.0	10.7	12.1	12.1	14.8	13.8	14.8
Draft—in. of water							
Furnace, operating floor	0.49	0.50	0.50	0.50	0.85	0.60	0.44
Furnace, apex	0.16	0.20	0.23	0.27	0.68	0.45	0.31
Boiler outlet	0.93	2.25	3.07	3.90	5.65	6.10	6.50
Economizer outlet	1.23	3.30	4.80	6.10	8.50	9.60	10.20
Air heater outlet	1.45	3.90	5.45	7.05	10.10	11.30	11.95
Flue gas analysis—per cent							
Boiler outlet—CO_2	15.15	14.7	14.5	14.3	14.0	14.0	...
Boiler outlet—O_2	3.5	3.5	3.9	4.2	4.4	4.5	...
Air heater outlet—CO_2	14.7	14.1	14.0	13.7	13.4	13.3	...
Air heater outlet—O_2	3.9	4.6	4.7	4.5	4.9	5.2	...
Proximate analysis of coal							
Volatile matter—per cent	30.9	30.7	31.3	31.5	31.3	31.3	...
Fixed carbon—per cent	60.4	61.8	61.7	60.4	60.2	60.2	...
Ash—per cent	6.4	5.5	5.7	6.4	6.4	6.4	...
Moisture—per cent	2.3	2.0	1.3	1.7	2.1	2.1	...
Heat value—Btu	13718	13971	13726	13713	13810	13810	...
Ultimate analysis—as received							
Carbon—per cent	77.5	77.7	78.3	78.0	77.7	77.7	...
Hydrogen (ex-moisture)—per cent	4.89	4.91	4.94	4.92	4.90	4.90	...
Sulphur—per cent	0.46	0.54	0.54	0.62	0.61	0.61	...
Size of coal							
Through 100 mesh—per cent	86.2	87.8	83.8	82.2	85.0	85.0	...
Through 200 mesh—per cent	65.4	65.2	60.6	59.4	63.4	63.4	...
Refuse analysis							
Combustible in ashpit refuse—per cent	0.0	0.2	0.0	0.3	0.0	0.0	...
Combustible in flue dust—per cent	18.9	25.8	28.5	26.7	23.3	23.3	...
Heat balance—per cent							
Dry gas loss	4.64	5.48	6.05	6.57	7.07	7.17	...
Moisture and hydrogen in coal	3.69	3.68	3.69	3.78	3.86	3.86	...
Moisture in air	0.06	0.07	0.08	0.08	0.11	0.11	...
Combustible in refuse	0.95	1.20	1.46	1.53	1.24	1.24	...
Radiation	1.98	1.40	1.15	0.85	0.60	0.50	...
Total losses	11.32	11.83	12.43	12.81	12.88	12.88	...
Efficiency—by difference	88.68	88.17	87.57	87.19	87.12	87.12	...

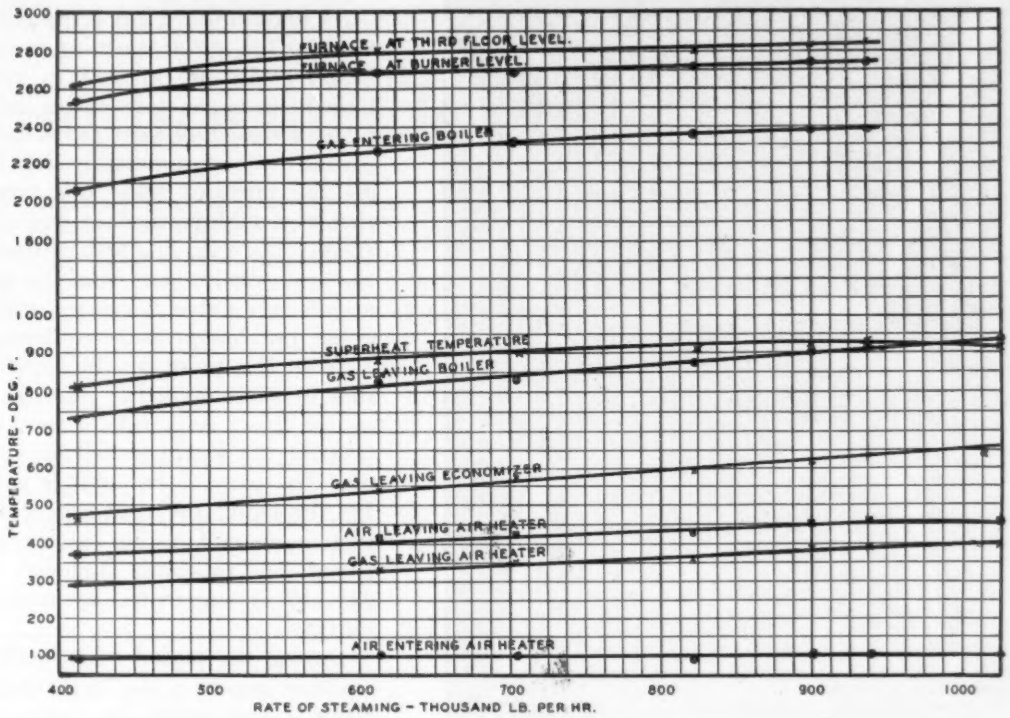


Fig. 5—Curves showing temperature measurements during test

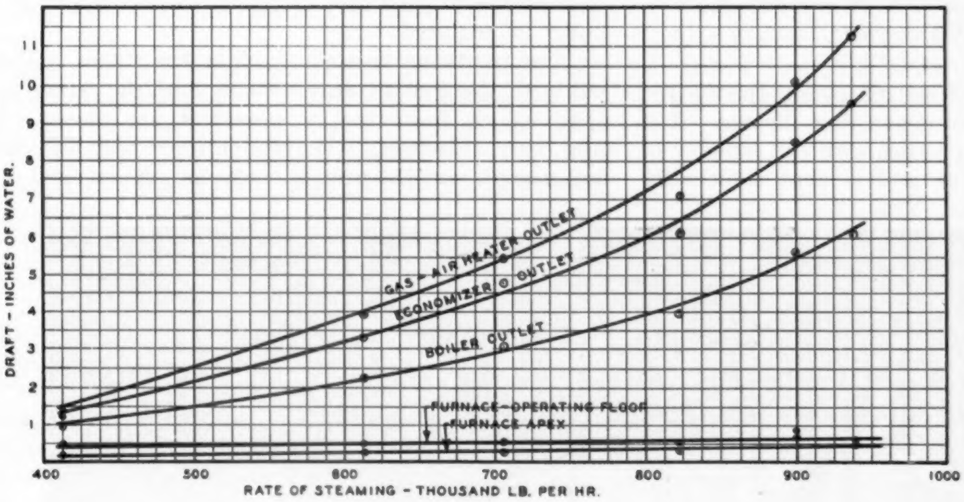


Fig. 6—Curves showing draft plotted against output

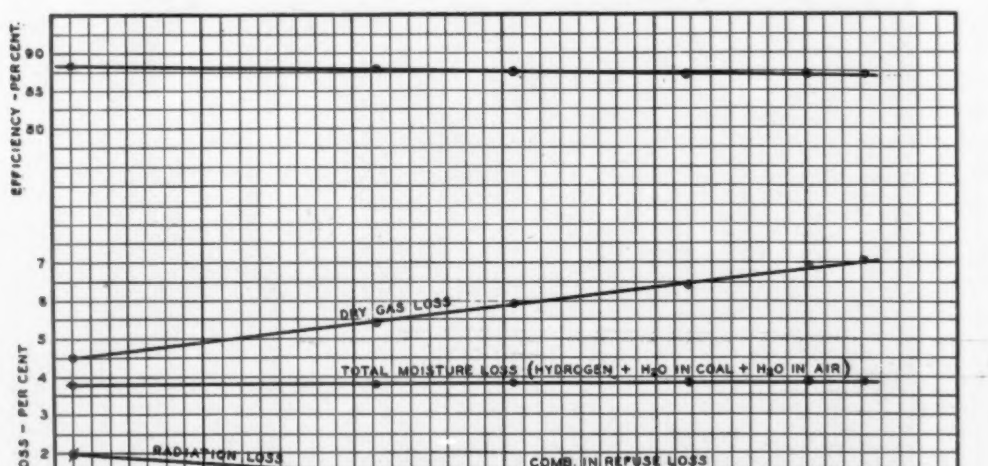


Fig. 7—Efficiency and losses at different outputs

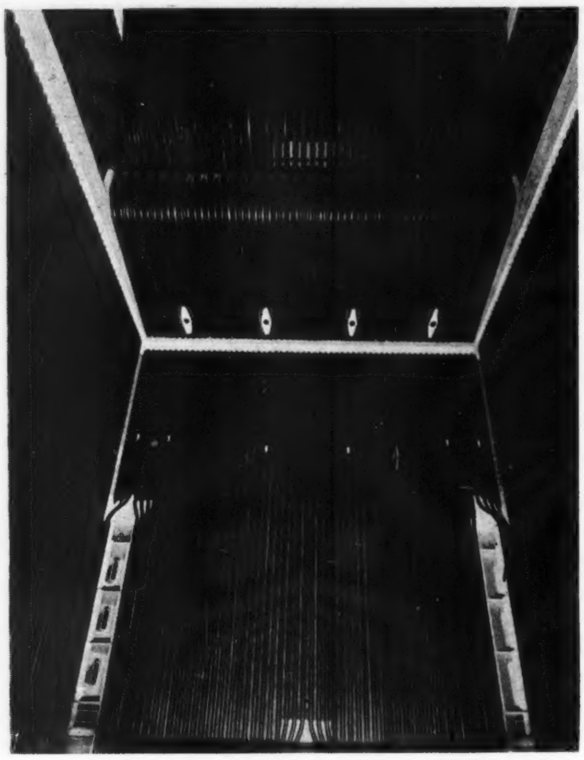


Fig. 8—Interior of furnace of No. 5 unit showing combination burners

the regular boiler feed pump and returning the desired quantity of water to the deaerating heater. The amount of recirculated water varies with the rapidity of bringing the unit on the line and is kept sufficiently large to avoid generation of steam in the economizers.

As blast-furnace gas is usually available, this fuel is used for the initial warming up of the unit. The superheater vents are opened to the atmosphere and the blast-furnace gas burners are lighted by means of small pilot lights. Sufficient gas is burned to raise the boiler pressure to approximately 250 lb in about two hours. As the pressure rises, the superheater vent valve is throttled slightly to hold down the quantity of vented steam. As soon as a boiler pressure of 250 lb is reached, the atmospheric vent from the superheater is closed and a spill-over valve is opened which allows the steam to enter the low-pressure system.

From this point on the rapidity of raising the pressure depends upon the time the boiler is required to go on the line. As a rule, a total of six hours is required to raise the steam to full line pressure, but more time may be taken if the unit is not required immediately. By throttling the spill-over valve to the low-pressure system, a small gas fire can be used to raise the pressure to full line pressure. Usually, however, the supply of gas fuel is augmented by means of one or more coal burners.

During the period of bringing the boiler up to full working pressure, the feedwater pressure on the economizer is kept above the boiler pressure, so that water is available at all times to replenish the supply in the boiler as required.

After the boiler goes on the line, the steam spill-over valve to the low-pressure system and the water spill-over valves from the economizers are closed. The feed valves between the economizers and the boiler are opened, and the unit is ready for regular operation.

Fig. 9—Taking readings at boiler operating panel during test

Combustion Instruments and Control at Hell Gate

By PAUL W. KEPPLER, Testing Engineer
Consolidated Edison Company of New York, Inc.

Of the twenty-six steam-generating units installed at Hell Gate Station, New York, twenty-one are stoker fired and five pulverized-coal fired. Of the latter the two largest units have combustion control and are completely equipped with indicating and recording instruments. The operating procedure employed with the several groups of units is described in detail and the maintenance and care of the instruments is discussed.

With the growth of this station the use of instruments and controls has advanced in geometrical progression. The earlier boilers have little more than Bailey boiler meters and push-buttons for the variable-speed fan motors. The latest have remote starting equipment for the mills and feeders, elaborate manual and automatic controls of all auxiliaries, and instruments at the central board indicating all drafts and temperatures from blower to stack, the current of nearly every motor, drum level, pressures of water and steam at many points, speeds of fans and feeders, in fact—almost every value of interest.

The earlier units are stoker-fired, there being seven rows of three boilers each. Four of these rows are made up of 165,000-lb per hr boilers and three of 250,000-lb per hr boilers. For these few instruments are used because actual observation of the fire is both necessary and sufficient. Air zoning is not employed as extremely high fuel-burning rates are not required. Besides the boiler meter only a furnace-draft indicator is used on each unit.

Row No. 8 consists of three pulverized-coal-fired boilers, each of 400,000 lb per hr capacity and served by four impact mills. They, too, require no control instruments. Their primary air supply is simply left wide open all the time. As operated, the minimum output of each unit is about 150,000 lb per hr. All four mills per boiler are always used because each fires one corner of the furnace tangentially. Mill air flow increases as capacity drops, but even at 40 per cent of mill capacity, the air flow is not too high for fine grinding. Moreover secondary air at that output is not too low to keep the burners cool because the tip area is small and nearly all the exposed parts are cooled by both mill and secondary air. It is necessary however, at very low outputs, to dam up the secondary air by closing the burner inlet damper. A gage is provided for this purpose at each burner between this damper and the main air duct. By reducing all burner dampers to the same opening and thereby creating a duct pressure of several tenths of an inch of water, uniform distribution of secondary air is assured at very low outputs. At and above 50 per cent capacity these dampers are left wide open, and practically no regulation is necessary. Only the total air is regulated to maintain the correct air-to-coal mixture. Absence of mill air regulation is conducive to better coal distribution and results in nearly balanced pressure at the feeder.

Regulation by the mill inlet damper would put this feeder under so much suction that coal would leak past the feeder in appreciable quantities. Balanced pressure at the feeder makes it possible to distribute the coal evenly, simply by running the four feeders at the same speed. Satisfactory combustion is automatically achieved by the tangential turbulence. The furnace draft is so regulated that at low outputs the furnace pressures are almost exactly balanced at the top. At higher outputs this section is gradually raised up to 0.2 in. at full output, because the impact of the tangential flames would otherwise cause local pressures at the furnace walls.

Combustion Control on Large Units

Row No. 9 consists of two boilers each of 1,000,000 lb per hr capacity. Similar conditions prevail at the burners as on Row No. 8, but ball mills are used and these require careful air adjustment to produce fine grinding. The most important indication is that of mill air flow. This cannot be obtained from any kind of mill or burner pressure where air and coal mixtures are involved. Such readings invariably give an indication of the mixture of air and coal flow. The same air flow gives low pressure readings at low loads and high readings at high loads. The result is that operators tend toward providing too much mill air at low loads, and vice versa. There was no room for orifices or the like to measure clean mill air.

Therefore, screens were used at each mill blower outlet ahead of the mill and the pressure drop was carefully calibrated with pitot tubes. The screens are $^1/_{16}$ in. brass plates with $^{11}/_{32}$ in. holes on $^1/_2$ in. centers. The maximum pressure drop is about 0.8 in. of water. Inclined gages are employed to avoid inaccuracies. The actual air flow adjustment is made manually by operating

a damper at the mill blower inlet by means of a cable from the central board. Other air pressures are also indicated, before and after the mill blower, in the middle of the mill between the two ball races, and at the mill

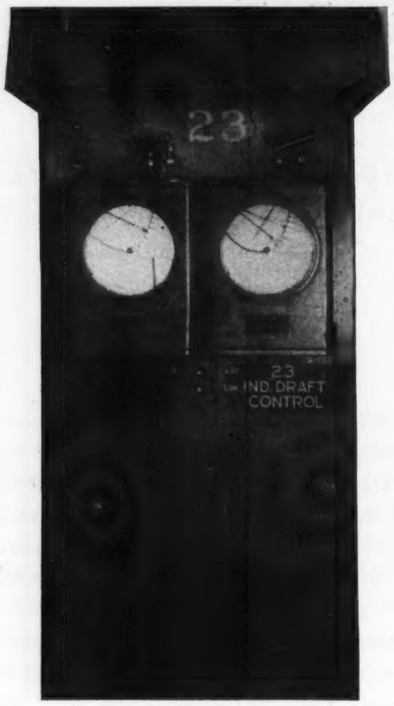


Fig. 1—Control panel of one of the earlier 165,000-lb per hr stoker-fired boilers

outlet. Feeder tachometers, remote indicators of Richardson scale counters and ammeters complete the mill instruments.

These mills also have remote starting equipment from the central board, which is a great convenience during lighting up and when changing from three to four mills. Three-mill operation is feasible here because each mill fires all the way across one of two sides of "opposed" firing. It is extensively used because heavy loading of this type of mill reduces both maintenance and auxiliary power. Less than three mills cannot be used because of standby requirements. The boilers are of twin construction, consisting of two straight-tube boilers over a common furnace. The Bailey boiler meters, therefore, are also of twin construction, but one chart reads the total air and total steam flow, and the other the air and the steam flow of one of the twin halves.

Automatic Combustion Control

The automatic combustion control was laid out to suit local requirements. Its purpose was to relieve operators of having to follow up a load that is variable due to frequency regulation. Purely mechanical adjustments in coal and air flow that have to be continually changed with load can be made better by mechanical devices which have a continuous hold on the auxiliaries and can easily be "regimented." Manual control can at best only approximate coordination of the operating steps.

"Smooth running" was one of the main objectives in this case and it was desired to change the rate of combustion as little and as slowly as possible. Rapid and radical changes would tend to produce smoke because of unnecessarily high burning rates and because of deposits being suddenly picked up from tubes, baffles, etc. Moreover, sudden changes are hard on the auxiliaries, refractories and other sensitive equipment, and efficiency would be impaired by excessive fuel burning rates or by priming. Also, drum levels in certain boilers are very sensitive. Where rapid response is required, those of the boilers that cannot develop it will not at first fully participate in the load change which will then be absorbed by the quicker units. Later on, the slower equipment adds its full share and overtravel and hunting results. It is even difficult to stabilize the automatic combustion control as well as other automatic apparatus of one unit within itself if fast changes are made.

An extreme case in this connection is the forced-draft regulation on Row No. 9. The forced-draft fan is turbine-driven. The regulator is very sensitive in order to maintain the furnace draft within a few hundredths of an inch of water. This turbine receives its steam at low pressure (around 20 lb at low outputs) from the turbine driving the induced-draft fan and exhausts into a feedwater heater at around 5 lb at low outputs. Regulation is entirely satisfactory providing conditions are smooth, but were a radical change to take place, such as a sudden and great increase in output, the feedwater regulator would almost stop the flow of water, the heater would immediately blow off at 35 lb pressure, and hunting and considerable error in furnace draft would be inevitable, in addition to loss of exhaust steam. Smooth running completely takes care of such difficulties and is achieved by purposely permitting the steam pressure to drift and allowing the boilers to act as accumulators. The normal steam pressure is 265 lb. Due to superheater drop the drums have a working pressure of 300 lb and the superheater safety valves are set for about 295 lb. The steam pressure is permitted to drift freely from 260 to 285 lb.

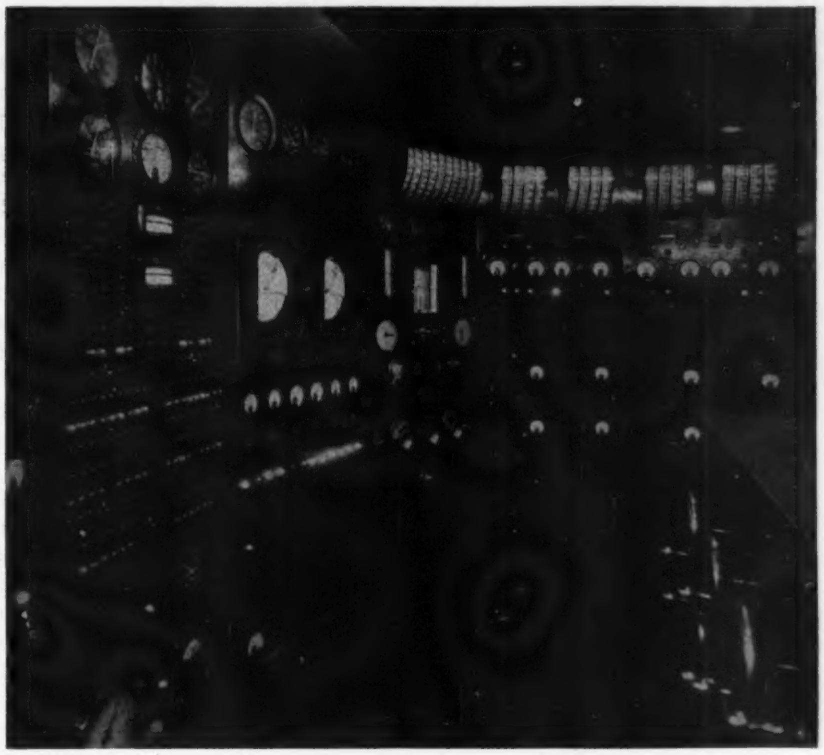
The arrangement employed for this purpose resembles the governing of main units prior to automatic frequency regulation. There the governor picked up load, but permitted the frequency to drift slightly; that is, load pickup was approximately proportional to change in frequency. Afterward the operator brought back the frequency by resetting the governor with the "auxiliary spring" adjustment. In the same way our combustion control changes output but permits the steam pressure to drift. The control operator prevents excessive drift or changes steam pressure in anticipation of the load by resetting the control. The change in output per pound of steam pressure is only about two per cent.

Explanation of Steam-Pressure Regulation

Fig. 3 explains graphically how the steam pressure regulation works. A sudden load increase, for example, results in a sudden drop in steam pressure from A to B. This is due to the drum pressure momentarily holding firm because of the accumulator action of the boiler. The drop through the superheater and the piping increases, and the main steam pressure therefore suddenly dips. After that it continues to fall but more and more gradually, for the accumulator action of the boiler and the rise in combustion rate supply more and more of the extra energy required. Both approach their final condition very smoothly. The operator resets the control at C if he considers this necessary. Originally no delay was interposed between this adjustment and the combustion rate so that the dotted curve CDE resulted.

Fig. 2—Control panel of one of the 1,000,000-lb per hr, unit-mill-fired boilers

First panel from the left: Remote temperature indicators (top) and remote operating signals (bottom). This is common to both boilers Nos. 91 and 92.
Second panel from the left: Bailey meters (top) and remote manual controls (bottom).
Third panel from the left: Boiler draft gages (top) and Smoot automatic control board (bottom).
Fourth and fifth panels from the left: Mill draft gages (top) and mill-starting equipment, etc. (bottom) for the four mills.
In the right foreground: Wheels for remote operation of mill-air dampers. This is common to both boilers Nos. 91 and 92. This desk also contains a telephone switchboard.
The mill-air-flow, inclined gages could unfortunately not be included. They are to the right, facing the operator as he operates the mill-air dampers.



That introduced a slight shock in combustion rate. A delay device was therefore added resulting in curve *CF*. This also reduces the total change in combustion rate; for the steam pressure, while rising, constantly tends to lower this rate and establishes a balance between itself and the impulse that is gradually coming across the delay device. Careful observations of the wattmeters of the main units indicate that there is no overtravel of the combustion rate beyond the change in load; the change in combustion rate is always much smoother than the change in load; and in many cases it is even less extensive because a reversal in load change often takes place.

The resetting of the control to avoid excessive drift and to anticipate load changes does not require many adjustments. During the week preceding the writing of this article 258 adjustments were made, the average interval between adjustments being 39 minutes. The presence of a control operator is essential for many other reasons. He serves as a sort of boiler-room load dispatcher ordering, for example, the starting and stopping of many auxiliaries, also boilers, for during the midnight shift pulverized-coal-fired boilers are shut down.

This arrangement for steam pressure control is the result of extensive experimentation and study. Many possibilities were looked into or actually tried out such as automatic resetting of steam pressure, impulses from the station load, and devices responsive to the change in the rate of drift of steam pressure, but none of these could give greater stability and flexibility. The device for regulating steam pressure is extremely simple and therefore very reliable and easy to maintain.

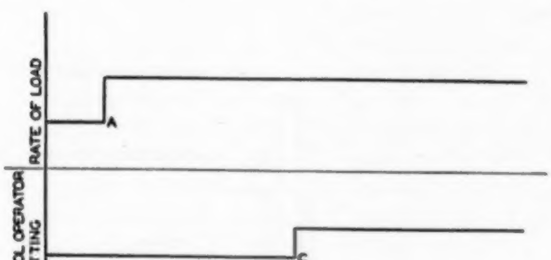


Fig. 3—Graphic representation of steam-pressure regulation

Operation of the Stoker-fired Boilers

On the stoker boilers air flow alone is controlled. Our underfeed stokers have so great a storage capacity of fuel that the stoker can be stopped for several minutes without materially damaging the fire. Few adjustments in coal feed are required. These are readily made by the fireman. Regulation of air flow takes care of the output, for the fuel bed gives a practically uniform CO_2 regardless of air flow; 10 per cent more air flow gives 10 per cent higher combustion rate. Fourteen forced-draft fans driven by brush-shifting, a-c motors discharge into a common duct from which all seven rows of stoker boilers are fed. All fourteen fans are used, if available, for the sake of fan efficiency. Each fan for electrical reasons had to be given an individual regulator. To keep all the fans in parallel the total head (static plus velocity) is used at each fan, but the flow per fan (velocity head) varies over a wide range due to boiler outage. The static head therefore also tends to vary for the same boiler output. The control operator was therefore given an indicator geared to the control telling him what this static pressure should be at any moment. He is

also given an adjustment of the total head that each regulator is to maintain at its own fan, and therefore adjusts the total head so that static pressure fulfills the control requirements. For a given number of boilers and fans very little change in this adjustment is required. The pressure maintained at each output is slightly in excess of that actually required by the stoker. The difference is throttled away by a windbox damper, the regulator of which controls the furnace draft. This is maintained nearly balanced at the top of the furnace. To give the fireman a maximum of protection without jeopardizing regulator stability, this regulator was given much more speed for closing the damper than for opening it. The air quantity is finally measured by the induced-draft regulator, that on the older rows shifts brushes of the motors or on the more recent units operates vanes on the fans driven by two-speed motors. The induced-draft regulators have an adjustment to compensate for dirtiness of convection surfaces. This adjustment is made as needed by the maintenance mechanic.

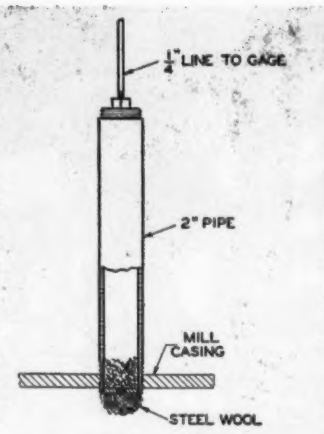


Fig. 4—Filter for gage connections on mills

Maintaining Load Distribution

Jointly with the rows of stoker-fired boilers, those fired by pulverized coal are so controlled that the load distribution approaches that of maximum efficiency taking into account smoke abatement, wear and tear of auxiliaries, etc. In general, it pays to load up the pulverized-coal-fired units more rapidly than the stoker-fired units because their efficiency curve tends to be flatter. Here individual forced-draft fans are used so that one forced-draft regulator per boiler is sufficient. Otherwise, air control is similar to that of the stokers. Obviously, control of coal flow is here necessary. On Row No. 8 (impact mills) there is a delay of about 30 sec between the change in feeder speed and mill output. This was taken care of by also delaying the air flow 30 sec so that coal and air flow at the burner always have the right proportions. This delay naturally slows down the whole boiler to some extent. This, however, is not objectionable because the control does not move very fast. Limitations in air flow also had to be taken care of in regulating coal flow. There are three fan speeds, and vanes are used for regulation on both the forced- and the induced-draft fans. The air flow obtainable at one fan speed is limited by vane leakage in one direction and by the speed used in the other. Coal flow must be prevented from going beyond these limits, and maximum and minimum adjustments had to be incorporated in the control. These must be set by the operators because they change with the fan speed used. All fan speeds are changed manually.

On Row No. 9 ball mills are used and these are still slower than the impact mills of Row No. 8. Most of the mill is filled with a mixture of air and coal, and the density of this mixture must be changed before output can complete its change. This takes minutes unless the coal feed is overtraveled. Slow mill action makes the boiler still slower, for after the flames have reached their final intensity the metal and refractory continue to absorb some of the added energy. The stoker-fired boilers with instantaneous change in flame intensity are found to take from one to two minutes to come close to their new output level. This, of course, is due to the necessity of bringing the entire unit to a new temperature level, the fuel bed, the metal, the water, the brickwork, etc. Row No. 9 with a slowly changing flame intensity naturally tends to take much longer to complete the change than the stokers. Parallel operation with stokers then becomes difficult. Overtraveling of coal feed has solved this problem very satisfactorily. For example, if a sudden rise in output from 500,000 to 550,000 lb per hr were required the coal feed would rise to that corresponding to 1,000,000 lb per hr and then gradually return to 550,000 lb per hr. The device is so set that the mill output reaches 550,000 lb as fast as possible but does not exceed it; for that would cause smoke and would not conform with smooth running. Of course, sudden changes never occur, and the overtravel of the coal feed under the usual smooth conditions is seldom more than fourfold.

Mill air is not controlled automatically but readjusted manually from time to time as needed due to change in coal or major change in output. The great complication of doing this automatically did not appear justified. While this regulation appears somewhat elaborate it should be kept in mind that there is only one coal feed regulator for four mills. Also, the overtraveling device itself is extremely simple. Careful tests indicate that during major changes in output the maximum error in CO_2 due to overtravel is only 0.3 per cent. This, of course, disappears as soon as the change is completed.

Maintenance of Control Instruments

The maintenance of these instruments and controls does not present very great problems. On draft connections to air and coal mixtures steel wool filters, Fig. 4, are used successfully. To prevent oil-sealing furnace draft and other bells from being "sucked over," the oil

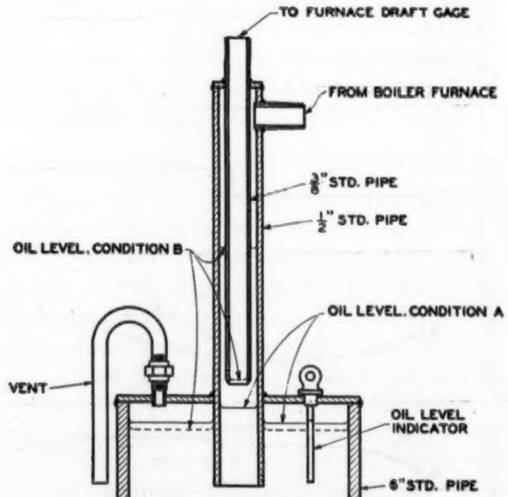


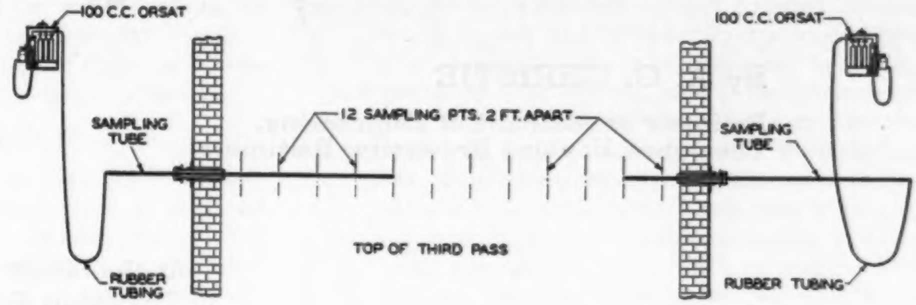
Fig. 5—Seal for furnace draft gage

seal shown in Fig. 5 is used. Normally, the oil level is at *A*, but should the suction temporarily rise beyond the meter range the level would rise to *B* and interrupt the connection between the furnace and the bell. A manufacturer furnished a similar device designed for mercury.

It failed to work. Careful examination showed the trouble to come from building vibration, causing ripples in the mercury and preventing it from sealing. The oil seal works very well. Where high suctions come within the working range of instruments, such as on the bells of some boiler meters, mercury seals are used instead of the usual oil seal. Such bells have to be weighted down, otherwise they will not hang straight due to buoyancy. Otherwise, they work perfectly. Boiler meters are checked once per month and reset as needed. The checking is done by an Orsat at the boiler outlet at as many points as, by careful experiments, are found necessary for getting a representative sample. On Row No. 9 (twin boilers) a total of twelve such points are used; six on Row No. 8; and again twelve on the stoker-fired boilers where considerable and variable stratification exists. Due to using so many points, usually with two Orsats, it is not necessary to make many traverses. Two of these have been found sufficient for one output. Of course, the traverses are not started until conditions have stabilized, and constant output is maintained on the boiler during and some time before the traverses.

On Rows Nos. 8 and 9 permanent lines are installed and a compressed air aspirator is used to get the sample to the Orsats. A bubbling bottle serves to indicate the rate of flow of aspiration. The lines are tested for tightness about once a year. On the stoker-fired units two removable pipes are used (Fig. 6); $^1/_8$-in. steel tubing is held in $^1/_2$-in. standard pipe welded to it on one end only. Fig. 7 shows the construction details of the sampling tube. The $^1/_2$-in. pipe is marked off and shifted from position to position. Small rubber tubing, $^1/_8$-in. inside diameter, is used to get the sample to the Orsat. The volumetric content of tubing between the Orsat and sampling point is only about 60 cc so that one draft of the standard 100 cc Orsat purges the line.

Fig. 6—Layout for CO_2 traverse of stoker-fired boilers



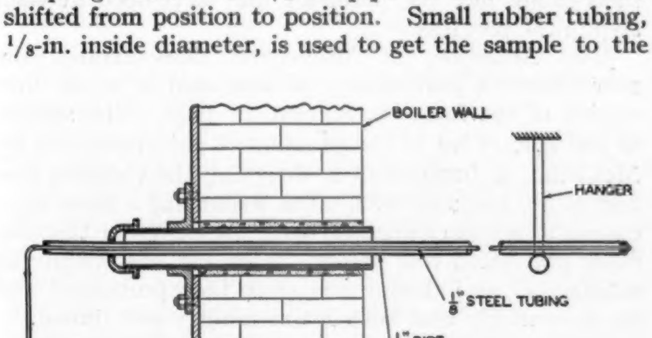


Fig. 7—Detail of sampling tube

Complicated mixing apparatus was purposely avoided because of time required for setting things up, the danger of leaks, etc., and also because knowledge of stratification is considered desirable. Enough excess air is used to practically eliminate unburned gases or excessive carbon in refuse losses, as well as to protect the stokers and to keep down slagging of the bottom rows of tubes. Careful experiments were made in this connection. While the excess air is determined, the blue and red pens are marked, and finally averages of total air and of blue and red pen readings are calculated. The monthly check is made at or near the average output of the boiler.

If resetting is found necessary, several outputs are checked, and the differential draft across the Bailey bells is observed together with the excess air on an inclined gage and a curve is drawn of this draft against air flow corrected to standard excess air conditions. Next, the meter is readjusted to follow this curve by the usual methods (shifting dead weight, adding or removing mercury, shifting the mercury displacer, etc.).

Such adjustments tend to destroy the accuracy at very low outputs, and displacers were therefore frequently redesigned following a true curve from zero up. Designing a displacer is easy if graphical methods are employed. The displacer would be a cylinder if the curve of draft loss against output were a straight line. By replacing the actual curve by a series of segmental straight lines, a displacer composed of a series of cylinders may readily be designed. These cylinders can then be rounded off into a smooth body that reproduces the draft curve very faithfully.

Aside from the foregoing, maintenance of combustion instruments and controls does not present many difficulties. Draft connections have to be blown out periodically, a certain amount of lubrication is required and leaks must be detected and the joints made tight. Beyond this extensive routine maintenance has not been found necessary.

One outstanding experience gained is that it pays to plan carefully and to eliminate thoroughly unforseen troubles. In many cases instruments and controls can be very simple. In other cases more elaborate control apparatus is desirable because it simplifies operating procedure. Where the choice lies between extensive equipment and complicated operating methods, it is usually better to make the operator's work simple even though the equipment becomes rather elaborate.

Twenty-Five Years of Power Development

By A. G. CHRISTIE

Professor of Mechanical Engineering,
The Johns Hopkins University, Baltimore

At the recent Twenty-Fifth Anniversary of The Johns Hopkins School of Engineering the author read a paper on "Progress in Power Development" in which were reviewed the advances that have been made during that period leading up to present practice. The latter is familiar to COMBUSTION readers and will be touched upon only briefly but some high spots of the progress from 1912 to 1937 are given.

THE 1912 plant had steam pressures in the range of 200 lb per sq in. with temperatures of about 600 F. Boilers with horizontal water tubes seldom exceeded 10,000 sq ft in size and few had economizers. Furnaces were comparatively small with about 7 ft between the stoker and the boiler tubes. Walls were made entirely of refractories. Underfeed stokers were being installed, although many overfeed stokers were still in use. New units were mostly steam turbines, though generators driven by Corliss engines were still operated. Most auxiliaries were steam driven, using the exhaust steam to heat feedwater to about 210 F. Little attention was given to feedwater treatment. Turbine-generators were cooled by air drawn from the outside through spray washers. The best central stations produced a kilowatt-hour at a fuel consumption of about 2 lb of coal or for about 25,000 Btu per kwhr.

The operation of such plants involved heavy labor in stoker operation, ash handling and maintenance. While records were kept of plant performance and efficient operation was an objective, much was lacking in a clear understanding of power plant economics.

Little change took place until the war period of 1917-1918. The great demand for power by the war industries required additions to many plants. The construction of new stations was started. Technically-trained men undertook the operation of central stations about this time. These men made a critical analysis of steam cycles, of generating equipment and of methods of efficient operation. Consequently, rapid development took place in power plant practice after the war.

Post-War Interconnection

The power shortage in some localities during the war period indicated the desirability of interconnection between utilities. W. S. Murray suggested a power interconnection between Washington and Boston. Colonel Junkersfeld, with Stone & Webster in 1920, proposed an interconnection of various plants in Ohio with the Youngstown-Pittsburgh district and studies were made of that project. Later on McClellan & Junkersfeld proposed a superpower system from Washington to Philadelphia, with Conowingo—then undeveloped—as a central generating point and with a steam plant at Holtwood, such as was built at a later date. Many interconnections of systems have been made since 1925.

A turning point in steam station development was a symposium presented in 1921 before the A.S.M.E. in New York on "Heat Balance in Steam Power Plants."[1] These and subsequent papers led to extended studies of heat cycles and to their application to power plants. The advantages of higher steam pressures and temperatures became evident and steps were taken to raise pressures first to 250, then to 300, 450 and 650 lb per sq in., and in 1923, 1200 lb was employed at the Edgar Station, Boston. Steam temperatures advanced to 750 F, but remained around that point for many years until metals were developed which were capable of withstanding higher temperatures.

Such changes in operating conditions were only possible as a result of developments in boilers, superheaters, turbines, generators and condensers. The designers and builders of such equipment deserve commendation for the marked success of their products and they have successfully met the problems that developed at each step in the progress.

John Anderson, at Milwaukee, demonstrated the possibilities of pulverized coal and used it in the first section of the Lakeside Station, in 1920. The success of this station led to the adoption of pulverized coal by McClellan & Junkersfeld in designing the Cahokia Station at St. Louis in 1923. The writer had a close association as advisory engineer with the design of this and other pulverized coal plants. Cahokia was equally as satisfactory as Lakeside and since then pulverized coal has been widely used both in this country and abroad.

The regenerative feedwater cycle, in which the feedwater to the boiler is heated by steam extracted from various stages of the main turbine, was probably first applied to turbines in England. This cycle was used on

[1] *Trans.* ASME—1921.

American turbines about 1922 and has been widely adopted in later plants.

J. R. McDermet, in a paper in Baltimore in 1920,[2] pointed out the need for the deaeration of feedwater and the means to accomplish this result. The use of an evaporator to produce absolutely pure makeup for boilers was old practice at sea. Among the first adoptions on land was that at the Huntley Station, Buffalo. All of these innovations were included in the Cahokia equipment despite strong opposition from certain quarters.

First Pulverized Coal Furnaces

The first pulverized coal furnaces were built with air-cooled refractory walls and a water-screen to cool the ash pit, and in the case of the first Cahokia boilers, with a screen of widely spaced tubes to afford some protection to the rear wall from the hot flames. This construction is still used when powdered anthracite is burned. The writer made a careful study of the performance of air-cooled refractory walls. Furnace and boiler designers at that time believed that cold furnace walls would chill the flame and that combustion would, as a consequence, be incomplete. My studies indicated that such would not be the result if proper combustion conditions were maintained. In a report to McClellan & Junkersfeld,[3] the writer showed that complete water-cooled walls were not detrimental but were essential for satisfactory service. The late Thomas E. Murray told me afterward that he read this paper on his way to England, and invented forthwith the fin-tube water wall which was one of the earlier forms of water walls and is still used in furnace construction. Other types of water walls quickly followed, and most recent furnaces are completely water-cooled. Some of the first furnaces almost completely water-cooled were those at Gould Street Station, Baltimore, where valuable experience was obtained upon circulation requirements, the necessary water volume of drums and the control of water levels.

Water-cooled furnaces require a high degree of turbulence. This led to the design of many mixing burners, among the earlier of which was the Bailey-Tenney burner, first installed in 1924 at the Ashley Street Station, St. Louis.

Water-cooled walls permitted higher furnace temperatures which led to the extended use of air preheaters, such as those at Gould Street. Economizers had been used at other stations, among which was Lakeshore Station, Cleveland. This plant contained boilers of 30,600 sq ft heating surface and were the largest in existence at that time. Upon test, in 1924, an efficiency of boiler, superheater, furnace and economizer of 92.9 per cent was obtained at 140 per cent of rating, which was an achievement at that time.

Among the first uses of the closed system of generator air cooler was that by Stone & Webster at Hartford about 1920, where the recirculated air was passed through spray washers and moisture eliminators. A closed-type of surface air cooler was installed in 1921 at the Amsterdam plant of the Adirondack Power Company, and this type has since been used in most plants.

As extraction heaters on the regenerative cycle provided hot feedwater, there was little use for exhaust steam from steam driven auxiliaries. The savings from the use of electric motors were then possible. At first, dual drives for auxiliaries, i.e., steam and motor, were provided to assure reliability. Then house turbines, house transformers both from the main bus and directly on the main generator terminals, and house generators were tried. All these systems are still used. A diesel-generator, set as a standby reserve to start electrical auxiliaries, was used by the writer in one foreign plant and deserves consideration for new isolated stations.

New problems, such as the caustic embrittlement of boiler steel, arose. This difficulty was overcome as a result of the studies of Parr, Straub, Partridge and Schroeder. In the meantime, Hall developed methods of boiler water control which have been widely adopted. Carryover of moisture with the steam resulted in closure of the blade passages of steam turbines and reduction of the turbine capacity. New steam purifiers, separators and washers have been developed which have reduced this carryover to small amounts.

The conditions favorable to the best utilization of cooling surface in condensers were pointed out by Paul Bancel in a paper at Baltimore in 1921.[4] Condenser designs have greatly improved since that time, while old condensers have been reconstructed. A. L. Penniman, on the Gould Street condensers, used tubes rolled at both ends into the tube sheets. Such construction practically eliminated leakage of circulating water into the condensate at the tube ends. This method is now widely used.

W. L. R. Emmett and his associates at the General Electric Co., developed the mercury boiler and turbine and several such plants are now in commercial operation.

Power Development in 1937

The present status of power development was reviewed at length by the writer in a paper on "Development and Performance of American Power Plants,"[5] at the September 1936 Niagara Falls Meeting of the A.S.M.E. The following brief comments present certain deductions from this more complete paper.

Practically all condensing turbines now operate on the regenerative cycle with as many as five extraction feedwater heaters, one of which usually serves as a deaerator. The vertical heater, first used by Penniman at Westport Station, is being used to an increasing extent. The evaporator for makeup usually forms an element in the feed heating system. The reheating cycle, while somewhat more efficient, has, in several recent cases, been replaced by the straight regenerative plant when the initial steam temperature is in the neighborhood of 925 F. The best recorded world performance of a condensing central station is that of the reheating plant at Port Washington, near Milwaukee, where operating conditions are 1230 lb per sq in., 825 F with 825 F reheat, which, for three months, averaged 10,900 Btu per kwhr at 53 per cent use factor. A newer plant with higher pressure and temperature could reduce this figure. Mercury-steam stations now in operation have shown performances of about 10,700 Btu per kwhr, although this may be reduced to about 9500 Btu per kwhr in future plants. In view of the relatively small savings that can be effected by the mercury plant, many engineers prefer the better known steam station.

[2] *Trans.* ASME—1920.
[3] Later published in *Power*, in 1923, under the title "The Influence of Radiant Heat on Furnace Design."
[4] *Trans.* ASME—1921.
[5] *Mechanical Engineering*, September 1936.

Superposition implies the addition of new high-pressure, high-temperature boilers to an old plant to furnish steam to a new high-pressure non-condensing turbine which exhausts into the present steam line at present operating conditions and thus to the older turbines already installed. This system will, in all probability, be applied to all stations over ten years old which operate at pressures between 200 and 400 lb per sq in., particularly where additional system capacity is required. The added output is secured at a heat rate of about 4000 Btu per kwhr, and, as a result, the overall station performance is substantially improved. Frequently, this addition of system capacity can be made at a lower cost than by any other method, particularly where much of the older plant can be embodied in the new layout. Superpositioned turbines are under construction up to 60,000 kw capacity at 3600 rpm. The electric generators of the larger units will be hydrogen cooled to reduce losses.

Steam generators up to 1,000,000 lb per hr at 1300 lb per sq in. are under construction. These new high-pressure units show radical departures from earlier practice. The evaporating surfaces are almost all designed to absorb radiant heat and furnaces are entirely water-cooled, frequently with bottoms designed to remove the ash as slag in a liquid state. Superheaters are designed to maintain constant temperature often by diverting a portion of the flue gases over economizer surfaces arranged in parallel with the superheater. Air preheaters are generally used. The trend is toward the use of pulverized fuel in such plants, as this system lends itself to larger capacities than stoker equipment. Up to the present, the forced circulation boiler has not been used here to any extent, although it is favored abroad, particularly in Germany.

This brief discussion indicates substantial progress since 1912. The end of development is not in sight, and one may reasonably expect continued progress in power generation through coming years.

Model of Conners Creek Boilers

The photographs reproduced on this page and on the cover are views of a model of boilers Nos. 1 and 2, of the eleven that have been installed or are under construction for the rebuilt Conners Creek power plant of The Detroit Edison Company. This model was built by E. C. Keithley, for many years Detroit resident engineer of The Superheater Company, as a hobby in his spare time. It required more than two thousand hours to complete.

It is made to a scale of three-quarters of an inch to the foot and stands four feet six inches high. More than five thousand rivets are contained in the steel frame, and the sixteen hundred brass tubes, of three different sizes, represent a total length of over twenty-seven hundred feet. These tubes, according to a description in the *Synchroscope*, house organ of The Detroit Edison Company, were bent to their proper shapes with a machine Mr. Keithley built for that particular purpose. The superheater contains three-hundred-and-forty elements.

The model is completely equipped with all the braces, clamps, joints, valves and fittings in miniature of those installed on the actual boiler.

It was presented to The Detroit Edison Company by Mr. Keithley and is now on display in its office building at Detroit.

Top view of Conners Creek model

Over 2700 ft of tubing was used

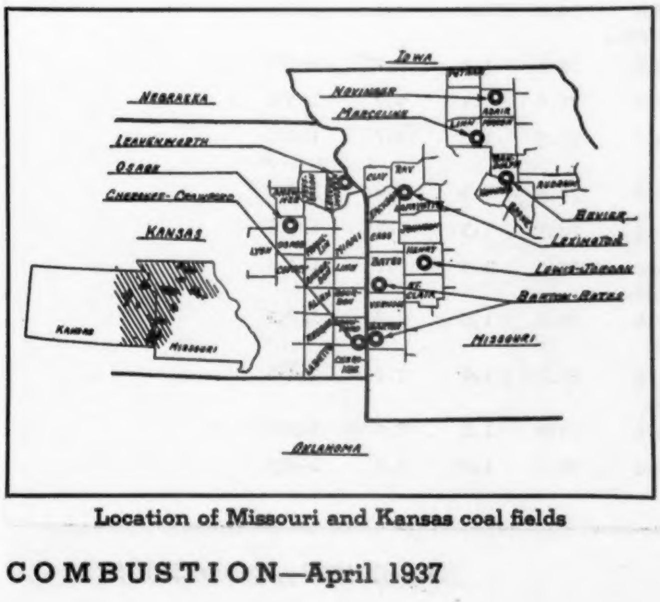
Kansas and Missouri Coals—Their Classification and Analyses

By P. B. PLACE
Combustion Engineering Company, Inc.

Previous articles of this series have dealt with Ohio, Kentucky, Virginia, Illinois, Indiana, Pennsylvania, Tennessee, Maryland and Alabama bituminous coals. In each case, as in the present article, the individual seams are traced through various counties, the coals are identified by county and trade names, and their characteristics and analyses are given. Knowing the source of a Kansas and Missouri coal, their moisture and ash content, a complete analysis may be set up from the values given in the tables which will be sufficiently accurate for most power plant purposes.

IN THE State of Kansas there is produced approximately four million tons of bituminous coal per year and the coal reserves underlie some twenty thousand square miles in the eastern part of the State. The extent of the coal-bearing area and location of the three principal mining districts are indicated on the map here shown.

The largest producing district in the State is the southeastern district with the bulk of the production coming from Crawford and Cherokee Counties. These two counties contribute more than four-fifths of the State's output and the principal seam mined is the Weir-Pittsburg which is locally known as the Cherokee coal. Other counties in this district are Linn, Bourbon and Labette.



Location of Missouri and Kansas coal fields

TABLE I

PRINCIPAL PRODUCING COUNTIES AND SEAMS IN KANSAS AND MISSOURI

	Kansas	Missouri
Principal counties	Crawford Cherokee	Barton Bates Henry Lafayette
Principal seams	Weir-Pittsburg Mulberry Bevier	Bevier Mulky Mulberry Lexington Tebo

TABLE II

GEOLOGICAL CLASSIFICATION OF KANSAS AND MISSOURI COAL-BEARING FORMATIONS

Group	Formation	Kansas	Missouri
Missouri	Wabauness Shawnee	Nyman seam Elmo seam Nodaway seam	Nyman seam Elmo seam Nonaway seam
	Douglass Lansing	Ransomville seam	
	Kansas City	Thayer seam	
Des Moines	Pleasanton	Mulberry seam	Ovid seam Mulberry seam
	Henrietta Cherokee shale	Lexington seam Lightning Creek seam Weir-Pittsburg seam	Lexington seam Mulky seam Rich Hill, Weir-Pittsburg seam Bevier seam Tebo seam Jordan seam

The northeastern district involves the counties of Leavenworth, Jefferson, Douglas, Franklin, Wyandotte and others, with the center of mining activity in Levenworth County. The principal seam mined in this area is the Bevier.

The Osage district is of only local importance.

The bituminous coal-bearing area in Missouri is in the northwestern part of that State, as will be seen by reference to the map, and is classified by some into six mining districts as follows:

1. Southwestern district in Barton, Bates and Vernon Counties.
2. Bevier district in Randolph, Boone and Macon Counties.
3. Lexington district in Lafayette, Ray and Clay Counties.
4. Lewis-Jordan district in Henry County.
5. Marceline district in Linn County.
6. Novinger district in Adair County.

Two-thirds of the State's production of bituminous coal comes from Barton, Bates, Henry, Lafayette and

TABLE III. Typical Individual Analyses of Kansas and Missouri Coals

As received		Moisture & ash free							
Moist.	Ash	Volatile matter	Fixed carbon	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	B.t.u./lb
Weir-Pittsburg seam - Crawford county - Kansas									
4.9	9.1	39.0	61.0	5.8	5.3	82.7	1.4	4.8	15040
6.8	8.3	38.9	61.2	3.6	5.4	83.4	1.6	6.0	15020
7.3	8.6	38.7	61.3	4.6	5.6	83.0	1.5	5.3	14940
7.4	8.4	37.7	62.3	3.1	5.4	84.0	1.6	5.9	15040
Mulberry seam - Linn county - Kansas									
8.2	14.8	41.0	59.0	3.7	5.7	82.1	1.6	7.0	14830
9.3	14.5	41.0	59.0	3.5	5.5	82.3	1.6	7.1	14770
8.5	12.3	40.8	59.2	3.6	5.5	82.5	1.6	6.8	14730
11.9	12.0	42.5	57.5	4.3	5.6	81.3	1.6	7.2	14600
Bevier seam - Leavenworth county - Kansas									
11.1	12.7	46.6	53.4	5.2	5.3	79.7	1.5	8.3	14520
12.0	13.7	47.4	52.6	5.9	5.4	79.3	1.5	7.9	14420
12.2	9.0	44.7	55.3	4.0	5.6	81.4	1.5	7.5	14580
12.1	16.1	49.3	50.7	6.6	5.3	78.7	1.5	7.9	14210
Bevier seam - Barton county - Missouri									
5.4	9.0	37.4	62.6	4.2	5.6	83.6	1.6	5.0	15170
5.9	11.5	37.5	62.5	6.1	5.4	81.8	1.3	5.4	14930
6.1	13.1	37.9	62.1	6.2	5.3	82.6	1.4	4.5	15110
6.3	6.5	40.5	59.5	4.3	5.5	83.4	1.5	5.3	15170
Mulberry seam - Bates county - Missouri									
12.2	12.2	40.1	59.9	3.0	5.5	81.3	1.7	8.5	14450
12.5	12.8	41.7	58.3	3.6	5.5	81.5	1.7	7.7	14630
12.3	10.7	39.4	60.6	2.7	5.4	82.1	1.6	8.2	14660
10.6	12.4	43.0	57.0	3.2	5.7	81.5	1.7	7.9	14690
Tebo seam - Henry county - Missouri									
10.6	11.5	47.8	52.2	4.6	5.4	79.4	1.2	9.4	14440
12.6	14.0	47.2	52.8	5.0	5.6	79.5	1.3	8.6	14580
9.1	13.0	48.1	51.9	4.9	5.6	80.3	1.2	8.0	14720
11.4	12.8	45.7	54.3	5.6	5.6	79.0	1.3	8.5	14530
Lexington seam - Lafayette county - Missouri									
12.3	11.3	45.0	55.0	6.0	5.9	77.7	1.4	9.0	14110
14.4	11.2	44.8	55.2	4.7	5.5	79.5	1.4	8.9	14370
13.4	14.3	44.3	55.7	4.3	5.7	77.3	1.4	11.3	14160
15.3	9.8	43.4	56.6	4.2	5.5	79.1	1.4	9.8	14360

TABLE IV. Average Analyses of Kansas and Missouri Coals

As received		Moisture and ash free							
Moist.	Ash	Volatile matter	Fixed carbon	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	B.t.u./lb
Kansas Coals			1. Weir-Pittsburg seam						
Crawford county									
5-8	6-10	38.9	61.1	3.9	5.4	83.5	1.5	5.7	15015
Cherokee county									
5-6	8-10	39.8	60.2	3.9	5.4	82.9	1.5	6.4	15100
			2. Bevier seam						
Leavenworth county									
10-13	9-16	47.0	53.0	5.4	5.4	79.8	1.5	7.9	14430
			3. Mulberry seam						
Linn county									
8-11	12-15	41.3	58.7	3.8	5.6	82.0	1.6	7.0	14750
Missouri Coals			1. Bevier (Weir-Pittsburg, Rich Hill) seam						
Barton county									
5-7	6-12	38.3	61.7	5.2	5.5	82.9	1.4	5.0	15100
Bates county									
7-10	12-15	45.0	55.0	6.5	5.7	79.5	1.4	6.9	14760
Randolph county									
11-15	9-14	45.8	54.2	6.3	5.4	78.8	1.3	8.2	14335
Adair county									
10-16	10-13	45.8	54.2	5.0	5.5	79.0	1.4	9.1	14325
			2. Lexington seam						
Lafayette county									
12-15	9-16	44.8	55.2	4.6	5.6	78.7	1.4	9.7	14320
Ray county									
13-16	7-12	45.1	54.9	4.6	5.5	78.6	1.4	9.9	14335
Adair county									
14-16	10-12	47.3	52.7	4.8	5.7	77.5	1.3	10.7	14200
			3. Tebo seam						
Henry county									
9-12	11-14	47.2	52.8	5.0	5.6	79.5	1.3	8.6	14570
Linn county									
12-15	7-9	47.6	52.4	5.4	5.5	78.7	1.3	9.1	14325
Adair county									
13-16	8-10	50.2	49.8	6.6	5.5	77.9	1.3	8.7	14315
			4. Mulberry seam						
Bates county									
9-12	10-13	41.3	58.7	3.5	5.5	81.6	1.6	7.8	14650
			5. Jordan seam						
Henry county									
9-12	10-13	43.9	56.1	5.1	5.4	80.2	1.4	7.9	14630
			6. Mulky seam						
Randolph county									
8-9	8-9	48.2	51.8	5.6	5.6	79.8	1.1	7.9	14590
Audrain county									
10-11	11-13	50.1	49.9	6.4	5.6	78.8	1.2	8.0	14455

TABLE V. Average Analyses of Kansas Coals

'Cherokee' coal	As Received	Dry or Moisture Free	Moisture and Ash Free	Moisture, Ash and Sulphur Free
Moisture	7.0	-	-	-
Ash	9.0	9.68	-	-
Volatile matter	32.76	35.22	39.0	39.0
Fixed carbon	51.24	55.10	61.0	61.0
	100.00	100.00	100.0	100.0
Sulphur	3.27	3.52	3.0	-
Hydrogen	4.54	4.88	5.4	5.62
Carbon	69.89	75.15	83.2	86.58
Nitrogen	1.26	1.35	1.5	1.56
Oxygen	5.04	5.42	6.0	6.24
	84.0	90.32	100.0	100.0
B.t.u. per lb	12640	13595	15050	15660
'Leavenworth' coal				
Moisture	12.0	-	-	-
Ash	12.0	13.64	-	-
Volatile matter	35.72	40.59	47.0	47.0
Fixed carbon	40.28	45.77	53.0	53.0
	100.00	100.00	100.0	100.0
Sulphur	4.10	4.66	5.4	-
Hydrogen	4.10	4.66	5.4	5.71
Carbon	60.65	68.92	79.8	84.36
Nitrogen	1.15	1.30	1.5	1.58
Oxygen	6.00	6.82	7.9	8.35
	76.0	86.36	100.0	100.00
B.t.u. per lb	10965	12460	14430	15360

TABLE VI. Average Analyses of Missouri Coals

Barton-Bates coal	As Received	Dry or Moisture Free	Moisture and Ash Free	Moisture, Ash and Sulphur Free
Moisture	8.0	-	-	-
Ash	12.0	13.04	-	-
Volatile matter	32.00	34.78	40.0	40.0
Fixed carbon	48.00	52.18	60.0	60.0
	100.00	100.00	100.0	100.0
Sulphur	3.76	4.09	4.7	-
Hydrogen	4.40	4.78	5.5	5.77
Carbon	65.60	71.31	82.0	86.04
Nitrogen	1.20	1.30	1.5	1.58
Oxygen	5.04	5.48	6.3	6.61
	80.0	86.96	100.0	100.0
B.t.u. per lb	11430	12965	14910	15645
Bevier & Lexington coal				
Moisture	10.0	-	-	-
Ash	12.0	13.33	-	-
Volatile matter	35.65	39.61	45.7	45.7
Fixed carbon	42.35	47.06	54.3	54.3
	100.00	100.00	100.0	100.0
Sulphur	3.90	4.33	5.0	-
Hydrogen	4.29	4.77	5.5	5.79
Carbon	61.23	68.04	78.6	82.63
Nitrogen	1.09	1.21	1.4	1.47
Oxygen	7.49	8.32	9.6	10.11
	78.0	86.67	100.0	100.0
B.t.u. per lb	11140	12370	14270	15020

Randolph Counties, and the principal seams mined are the Bevier (Rich Hill, Weir-Pittsburg), Mulberry, Lexington and Mulky.

A geological classification of the coal-bearing seams of Kansas and Missouri is given in Table II. The Missouri group is roughly comparable to the McLeansboro group in Illinois[1] and the Conemaugh (upper) and Monongahela group in Pennsylvania.[2] Similarly, the Des Moines group parallels the Carbondale group of Illinois and the Allegheny and Conemaugh (lower) groups of Pennsylvania.

The principal coals mined in these States are found in the Cherokee shale and many are commonly known as Cherokee coals.

In general, the coals are non-caking, high in moisture, ash and sulphur and their ash has a low fusion temperature which ranges from 1950 to 2100 F. These coals compete with coals from adjacent States and are used for locomotive, domestic and general industrial fuel. They are classed as free-burning coals and are best burned on traveling grate stokers or in pulverized form. Although a large percentage is sold as run-of-mine, there has been considerable progress in the cleaning and sizing of these coals for the market.

Physical Characteristics

Physically, the coal is similar to that of northern Illinois and Iowa. It is hard, blocky with laminated structure and has a tendency to weather and slack. Kansas coals are generally better coals than Missouri coals principally because the bulk of the Kansas production comes from its best grade district.

Typical Individual Analyses

In Table III are given typical individual analyses of various seams in Kansas and Missouri showing the normal variation in moisture and ash-free analyses of coals from the same area and seam. From similar lists, the average analyses given in Table IV have been prepared. Following the custom in this series on coals produced in the various States, the averages are given on a moisture- and ash-free basis. From these averages a complete analysis on an "as received" basis can be set up for a coal of known ash and moisture content. With high sulphur coals, especially those which have been cleaned, it is advisable to reduce the moisture- and ash-free values given in the tables to a moisture-, ash- and sulphur-free basis and calculate the "as received" analysis for known moisture, ash and sulphur contents.

Complete analyses of Kansas and Missouri coals are given in Tables V and VI which are sufficiently typical for general purposes. The moisture and ash values are assumed as average values. The moisture-, ash- and sulphur-free analyses are given for calculating the analyses to a known moisture, ash and sulphur basis. In both tables the better analysis represents the bulk of the production from the State, the second analysis representing the second grade coal.

[1] Illinois Coals—Their Classification and Analyses, COMBUSTION, September 1935.

[2] Pennsylvania Bituminous Coals—Their Classification and Analyses, COMBUSTION, April 1936. Pennsylvania Bituminous Coals—II, COMBUSTION, June 1936.

Locomotive Engineering in 1831

An item of unusual historical interest is contained in a copy of *The New York Spectator* dated January 14, 1831, which has recently come to our attention. This refers to an announcement by the B & O Railroad offering four thousand dollars for the most approved locomotive steam engine capable of drawing a load of fifteen tons on the level at a speed of fifteen miles per hour. The steam pressure was not to exceed one hundred pounds per square inch and it was stipulated that the boiler be equipped with two safety valves, "one of which must be completely out of reach or control of the engine man, and neither of which must be fastened down while the engine is working." Furthermore, it was to burn coke or coal and "must consume its own smoke." An hydraulic test of the boiler not exceeding three times the steam pressure was to form part of the acceptance tests.

As a result of this competition three locomotives were built, only one of which met the requirements. This was built by Phineas Davis at York, Pa., and was named the "York." It had a vertical boiler and was placed in service during July 1831 between Baltimore and Ellicott Mills, Md., a distance of fifteen miles, which it covered in slightly under an hour.

To one familiar with the modern steam locomotive this item is a forceful reminder of the progress in locomotive engineering during the past hundred years.

New Steel Specifications

Announcement is made by the American Society of Testing Materials that the Committee on Boiler Steels reports progress on four new specifications covering carbon steel, low carbon-nickel steel, molybdenum steel and chromium-manganese alloy steel plates of flange quality for locomotive boiler shells and of flange and firebox qualities for stationary boilers and other pressure vessels. A new specification for alloy-steel boiler and superheater tubes for high-pressure and high-temperature steam service is also being prepared. Futhermore, it is proposed to withdraw the present lists of specifications for steel suitable for fusion welding (A 151-35) and to revise them so as to incorporate specific requirements for welding.

Chicago Power Show

A new Power Show for the Middle West—the Chicago Exposition of Power and Mechanical Engineering—has been announced. The place is the new International Amphitheatre at Chicago, and the dates are October 4 to 9, 1937. It is to be under the same management which, over a long period of years, has conducted the New York Power Shows. The Chicago Show is not intended to supplant the Power Show at New York, nor to interrupt its sequence, the next one of which is scheduled for December 1938 at the Grand Central Palace in New York. No periodic holding of the Show in Chicago has yet been decided. The frequency of its repetition will be decided after the forthcoming Show has been held.

The Specific Enthalpy of Low-Pressure Steam

By C. HAROLD BERRY

Professor of Mechanical Engineering, The Graduate School of Engineering, Harvard University, Cambridge, Mass.

The author gives three simple equations for computing enthalpy, which are applicable, respectively, to three temperature ranges and which, for temperatures above 100 F, are in agreement with the latest steam tables within two per cent—a degree of accuracy that is acceptable for many purposes. A chart is plotted showing these differences.

SOME years ago[1] the author drew attention to a simple empirical equation for computing the specific enthalpy (Btu per pound) of low-pressure superheated or saturated steam with an accuracy adequate for combustion and humidity computations. The publication of the recent Keenan and Keyes Steam Tables[2] makes it appropriate to review the matter in the light of the new data and the extension to higher temperatures.

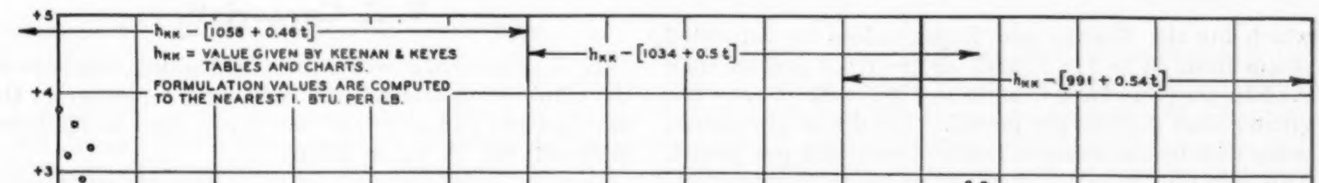
For pressures below 5 lb per sq in. abs, the specific enthalpy of steam is only slightly influenced by the pressure; it depends almost solely upon the temperature. Accordingly, in combustion and humidity computations, it is not necessary to know the partial pressure of the water vapor. The weight of vapor is computed by independent methods, and its specific enthalpy can be found with sufficient accuracy from its temperature alone.

[1] *Power*, March 17, 1925.
[2] "Thermodynamic Properties of Steam," Keenan and Keyes, New York, John Wiley & Sons, Inc., 1936.

When the temperature is known, the easiest way to secure the specific enthalpy is to consult the top line of the superheated steam table (corresponding to the pressure 1 lb per sq in. abs) where, by interpolation, the value can be found for any temperature up to 1600 F.

But sometimes it is preferable to formulate the specific enthalpy, either because the temperature is unknown, or for reasons of convenience. To this end, the equations that follow may be of service.

Since the enthalpy of vapor is a quantity of the order of magnitude of 1100 to 1800, the statement of its value to tenths of one Btu per pound implies in all related computations a degree of accuracy that is not attained in the cases to which these equations are intended to apply. Values of enthalpy within a few Btu per pound will be entirely adequate. Accordingly, linear equations have been chosen, and an effort has been made to select



Difference between values of *h* computed to the nearest single Btu per pound from equations (1), (2) and (3) and the values given by the Keenan and Keyes tables and charts.

Every point appearing in the tables below 5 lb per sq in. is plotted, and in addition there are plotted a large number of points based upon readings from the Mollier charts, both the printed chart accompanying the tables and the much larger chart of which blueprints are available through the A.S.M.E. headquarters office. The irregular location of the points is due to the fact that the equation values are computed only to the nearest single Btu per pound and to the difficulty of also reading the small Mollier chart with high precision.

their constants with a view to simplicity and convenience. The relation between enthalpy and temperature is represented by a curve. It is not possible to secure satisfactory accuracy by a single straight-line equation, and it appears that three equations are needed to cover the entire range acceptably. These equations are intended to be used to compute results only to the nearest single Btu per pound.

t from -40 to $+600$; $h = 1058 + 0.46\,t$ (1)

t from 600 to 1100; $h = 1034 + 0.5\,t$ (2)

t from 1100 to 1600; $h = 991 + 0.54\,t$ (3)

The temperature t in these equations is the ordinary Fahrenheit temperature (not absolute).

When values of h are computed to the nearest single Btu per pound by these equations, the results will agree with the values given by the Keenan and Keyes tables and charts to within 2 Btu per pound from 100 F to 1600 F. For temperatures below 100 F, and down to -40 F, equation (1) gives results lower than the tables by amounts ranging from about 2 to over 4 Btu per pound. The chart shows the distribution of the differences between the three equations and the Keenan and Keyes tables.

For many purposes, this degree of accuracy is altogether acceptable. Above 100 F, the accuracy is better than 1 part in 1000, except for a few restricted ranges where the discrepancy is slightly greater. Below 100 F the discrepancy rises from 2 to over 4 parts in 1000, which is usually negligible, especially since, in this region, only a very small weight of water vapor will be involved in combustion and humidity processes.

Equations (1) and (2) give identical values when the temperature is 600 F, and (2) and (3) give identical values at 1075 F. The discrepancy at 1100, however, is small, and this is perhaps a somewhat more convenient division point between the equations.

It is interesting to mention one other equation,

$$h = 1062.2 + 0.43\,t \qquad (4)$$

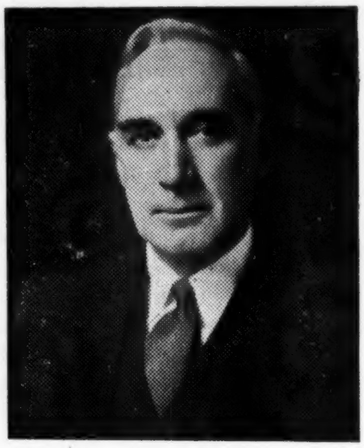
which fits the Keenan and Keyes values for saturated steam from 36 to 118 F with an error not greater than 0.1 Btu per pound and from 32 to 128 F with an error not greater than 0.2 Btu per pound. Results are, of course, computed to the nearest tenth of one Btu per pound. This equation, however, does not fit the values for superheated steam as well as does equation (1), and accordingly equation (4) can be used only when it is known that the steam is saturated. This considerably reduces its usefulnes.

In problems arising in humidity computations, it is customary to use the excess of enthalpy over the enthalpy of saturated liquid at the dew-point temperature or the wet-bulb temperature. For the low temperatures involved, the liquid enthalpy can be satisfactorily approximated by $(t - 32)$, and the subtraction of this quantity from the value given by equation (1) will serve to give the desired excess. It should be noted that the temperature, t, appearing in equation (1) is the actual temperature of the vapor, which is the dry-bulb temperature. The temperature for which the liquid enthalpy is wanted will be lower than this by an amount depending upon the atmospheric conditions. Accordingly, an algebraic representation of this difference will not be especially serviceable.

James D. Andrew

James D. Andrew, well-known engineer and for the past four years manager of the American Boiler Manufacturers Association and Affiliated Industries, died of pneumonia at his home in Englewood, N. J., on March 22. He was 62 years old.

Born in Brooklyn, N. Y., Mr. Andrew attended Columbia University and in 1899 became a mechanical engineer with the Metropolitan Street Railway Company of New York.



He was subsequently associated with the New York Edison Company, later became superintendent of power for the Boston Elevated Railway System, and then superintendent of engineering for the Edison Electric Illuminating Company of Boston.

During the war he was manager of ship construction at the Hog Island Shipbuilding Plant and later became vice president of Stevens & Wood, Inc., consulting engineers of New York. Other affiliations included the presidency of the Balsa Refrigerating Company and of the Standard Tank Car Company, consulting engineer for Armour & Company, and for a time chief engineer of the Niagara-Hudson Power Corporation.

He was a member of numerous engineering societies including the A. S. M. E., the A. I. E. E. and the Society of Naval Architects and Marine Engineers.

V. Z. Caracristi

V. Z. Caracristi, well-known consulting engineer in the combustion and railway fields and a pioneer in the development of pulverized-coal firing, died at his home in Bronxville, N. Y., on March 5.

Born in Richmond, Va., in 1876, his early engineering career was spent in the design of locomotives for the Richmond Locomotive Works and the American Locomotive Works. Following this he was a representative of the B. & O. on the construction of the Washington, D. C., terminal, and for a number of years consultant for the Wheeling & Lake Erie, and the D. & H. railroads.

In 1913 he organized the Locomotive Pulverized Fuel Company and developed the "Lopulco" system for burning pulverized coal under locomotive and stationary boilers, one of his early installations being at the Ford Motor Co.

When his company was merged with Combustion Engineering Company, Inc., in 1920, he became consultant for the latter as well as for The Superheater Company. At about this time he also developed, with Piron, a system for low-temperature distillation of coal.

During his lifetime, Mr. Caracristi was granted approximately three hundred U. S. patents covering combustion, locomotives and special tool designs.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Large Ljungström Turbines

At the Southwick Power Station of the Brighton Corporation Electricity Undertaking, England, there have recently been installed two Brush-Ljungström steam turbines each of 37,500 kw capacity. While machines of this type of greater capacity are in service on the Continent, these are the largest British-built Ljungström turbines yet installed.—*World Power*, February 1937.

Interconnection in France

According to *La Journée Industrielle*, marked progress has been made in the past few years in establishing an interconnected system of electrical distribution throughout France. Begun as regional schemes of interconnection these are now linked together into a grid of national scope which includes practically all the more important generating and distributing companies. A uniform frequency of 50 cycles has greatly facilitated this interconnection and extensive railway electrification has fitted into the scheme. Financing has been largely by private capital, as supplied by groups of producers and distributors, with some relatively small advances by the government, particularly in connection with hydro power. Regional control is exercised by boards supported by the producers and distributors.

Battersea Power Station and the Flue-Gas Problem

A proposal further to extend the Battersea Station of the London Power Company by the installation of a 100,000-kw main set, a 5000-kw house set and other auxiliary plants is made the subject of a report, which was presented by the Housing and Public Health Committee at the meeting of the London County Council on Tuesday, March 16. In inviting observations on this project the Electricity Commissioners stated that the power company would take the maximum advantage of the experience accumulated in the design of gas-washing plant and in the developments in technical knowledge on the subject of removing sulphur compounds from flue gases. It appears that the washers are to be improved by a rearrangement of the scrubbing surfaces, and of the design of the sprays and disposition and control of the water and alkali used, with better control of the gas velocities. A high-tension electrostatic plant is to be installed for dealing with the haze emitted from the chimneys about which some complaint has been made, but the suggestion that dissemination might be improved by reheating the gases is discounted on the grounds both that it would have no appreciable effect and that there is no practicable means of effecting it. Further research into the whole question is recommended.—*Engineering*, March 19, 1937.

Increased Power for South Africa

To meet the increasing demand for power in the Rand gold mining district in South Africa, Metropolitan-Vickers Electrical Company of England is supplying twelve 33,000-kw steam turbine-generators and four 7000-kw house service units to the Victoria Falls and Transvaal Power Company for installation in several of its stations and those belonging to the Electricity Supply Commission of South Africa which it operates. These additions, according to *The Engineer* of March 5, will bring the total capacity of this company up to 820,500 kw.

Material Requirements of the German Boiler Industry

Lack of raw materials for the highly developed industries of Germany and Italy is one of the principal reasons for the present political tension in Europe. Dr.-Ing. E. Schulz and Dr.-Ing. O. Schmidt in *Archiv für Wärmewirtschaft*, February 1937, show to what extent this condition affects the German boiler industry. They also discuss the way in which the German industry is coping with the problem under the Nazi "capitalistic collectivism" and its strict regulation of national economy.

The authors point out that of the raw materials required in modern boiler manufacture, Germany either does not produce at all, or produces only in negligible quantity, manganese, chromium, tungsten, nickel and copper. Even the domestic iron ore production was unable in 1936 to cover more than one-third of Germany's requirements.

In the last decade carbon steels have been developed which are sufficient for wall temperatures of up to 800 F at pressures up to 625 lb per sq in. For higher temperatures, however, alloy steels are considered necessary to withstand creep and scale formation. Their use permits a reduction in tube wall thickness and, in consequence, weight, which is of great importance for the export trade.

There exists a certain relationship between coal consumption and the steel weight of a steam generating unit. Greater weight of steel accompanying extensive heating surface means higher efficiency and lower coal consumption, whereas smaller heating surface results in lower efficiency and higher coal consumption. Weight increases faster than efficiency.

The authors remark that under present conditions it is advisable, in the interests of national economy, not to

put too much stress on high boiler efficiency, as Germany can cover 100 per cent of her coal requirements from domestic sources, whereas the installation of economizers or air heaters requires large quantities of steel. For the same reason, the manufacture of multiple-drum, bent-tube boilers in Germany is to be discouraged.

For capacities of up to 9000 lb of steam per hour return-tubular boilers are still the most economical, although their weight averages from 8 to 9 lb of steel per pound of steam generated. Water-tube boilers show a similar ratio of steel weight to steam, but have the advantage of lower space requirements. Greatly superior in this respect are forced-circulation boilers, and in particular the Velox boiler, which has a ratio of 1.5 to 4 lb of steel per pound of steam. From the German point of view, however, it suffers from the disadvantage that it requires a greater percentage of alloy steels.

By reducing tube diameters savings in weight can be realized, because the required wall thickness drops rapidly to the permissible minimum of 2.5 to 3 mm. Reduced tube weight results in savings in boiler house structural steel and boiler supporting steel. It also favorably affects drum header thickness due to changed tube spacing. These circumstances explain to a large extent the popularity of forced-circulation boilers in Germany.

Heat Insulation

J. S. F. Gard, in a recent paper before The Institute of Fuel (England), as reported in the March issue of *The Steam Engineer*, gives the following comparative figures on the insulating properties of 85 per cent magnesia, spun glass, slag wool and asbestos felt:

Material	Density lb per cu ft	"K" at mean temperature of 200 F	"K" at mean temperature of 400 F	Heat transmission through 2 in. thickness on 4 in. pipe at hot face temperature 300 F	Heat transmission through 2 in. thickness on 4 in. pipe at hot face temperature 600 F
85% magnesia	12	0.42	0.51	64 1/2	171
Spun glass	8	0.36	0.56	60	186
Slag wool	15	0.45	0.56	67	186
Asbestos felt	11	0.47	0.58	68	189

He points out that while spun glass shows a slightly better efficiency than 85 per cent magnesia at temperatures up to about 300 F, at higher temperatures the conditions are reversed.

Commenting on insulation for high temperature steam piping of the order of 750 to 1000 F he says that this has presented an entirely new problem for the manufacturers. For instance, 85 per cent magnesia loses mechanical strength and tends to break down at temperatures over 625 F owing to loss of water and carbon dioxide, the carbonate becoming more or less calcined to the oxide on the inner layers. Moreover, no composition containing organic fibers can be used, as charring and carbonization occur at temperatures over 400 F. There is a steep temperature gradient through the insulation and the more efficient it is, the steeper the gradient; hence, there is always a portion of the thickness that falls below the damaging temperature.

"Any insulation," he says, "that is suitable for these higher temperatures is of necessity heavier, less efficient thermally, and more costly. Thus the most economical way to provide insulation in such cases is first to apply a material which will not break down at these high temperatures and surmount this with the more efficient

material. The thickness of the first layer must be such that at the interface of the two the temperature is just below the limiting or safe temperature of the outer layer."

Personals

Ralph H. Tapscott, formerly vice president of the Consolidated Edison Company of New York, has been made president of that company, succeeding Frank W. Smith who will reach the retirement age in June.

L. B. Fuller has been advanced from superintendent of power to chief engineer of the Utah Power & Light Company succeeding **J. A. Hale** who was recently promoted to vice president.

C. F. Hardy, for the past eight years connected with the power department of the Chrysler Corporation, has lately joined the fuel engineering staff of Appalachian Coals, Inc. His duties will involve calling on power plants, assisting in analyzing their problems and advising as to coal selection.

Frank M. Van Deventer, for a number of years mechanical engineer in the construction department of Henry L. Doherty & Co., has lately joined The Walworth Company, New York.

C. A. Reed, who a few months ago assumed charge of the engineering department of the National Coal Association at Washington, has, in addition to these duties, lately been appointed secretary of Bituminous Coal Research, Inc., succeeding Oliver J. Grimes.

Daniel J. Saunders has been made manager of industrial sales for The Permutit Company, New York, manufacturers of water-conditioning equipment. He has been with the company for seventeen years and was formerly assistant manager of industrial sales.

Business Notes

Cyrus Wm. Rice & Company, Inc., water chemists and engineers, Pittsburgh, has lately appointed S. B. Whinery New York sales manager at 1 Hudson Street, New York, and H. C. Stevens as New York Division service engineer.

The Reliance Gauge Column Company announces the appointment of the following representatives: The Chas. M. Setzer Co. of Charlotte, N. C., for North and South Carolina; Eshelman & Potter of Birmingham for Alabama and Tennessee; and T. C. Messplay of Kansas City, Mo., for western Missouri and Kansas.

The Cochrane Corporation, Philadelphia, has consolidated the sales of equipment in New England under Cochrane Steam Specialty Company, 80 Federal Street, Boston, with O. S. Pike in charge of water treatment equipment and T. N. Graser handling steam specialties and meters.

The C. O. Bartlett & Snow Company, Cleveland, Ohio, has announced the appointment of Lloyd R. Leatherman to handle coal- and ash-handling equipment in Michigan. He is located at 2140 Book Bldg., Detroit.

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Steam Turbine Operation, Second Edition

By William J. Kearton

There are many excellent books on the steam turbine, but the majority of these deal with design, fundamental calculations and descriptive matter. This book is descriptive only to the extent of enabling the operating engineer to become familiar with the construction and design of certain well-known types of European and American manufacture. Its main objective is to provide practical information on the installation, operation and maintenance of such units. Warming up and starting are discussed at length as are also turbine failures, troubles, vibration, speed control and lubrication. Turbine testing is also covered.

In the present edition, the 1931 text has been brought up to date and chapters have been added dealing with regenerative feedwater heating and erosion of blading in the low-pressure stages of large machines. In connection with the latter, drainage arrangements and blade materials are discussed.

The book contains 346 pages, $5^1/_2 \times 8^1/_2$ in., with cloth binding. Price $3.75.

Coal—Its Constitution and Uses

By William A. Bone and Godfrey W. Himus

This is an 830-page treatise on the economic, geological, chemical and technological aspects of coal. Because of its British authorship the introductory chapters deal with present-day British coal problems, but the remainder of the text is largely fundamental and has world-wide application. The origin, formation and classification of coals are dealt with in comprehensive manner and the constitution of coals found in various countries is included, together with their proximate and ultimate analyses. A chapter on combustion reviews much basic information developed by numerous researches. Considerable space is devoted to the preparation of coal for the market and to various carbonization processes.

In connection with a discussion of the smoke nuisance and its abatement much data resulting from investigations in England are included and smoke abatement legislation is reviewed; also, the acid pollution problem is discussed.

The twenty pages devoted to pulverized coal and coal-oil mixtures seem rather inadequate for this important subject and necessarily precludes much detailed data and information concerning latest practice. Also, the authors' attempt to discuss boiler design and management is confined largely to British practice, is very sketchy and does not touch upon recent designs that are to be found in European or American practice.

Concluding chapters deal with fuel economy in the manufacture of iron and steel and in industrial furnaces, surface combustion, domestic heating and power production from coal.

As a reference on coal the book has much to commend it. Its price is $7.50 net.

The Recovery Problem in the United States

This volume presents the recent studies of a number of well-known economists under the sponsorship of the Brookings Institution, which, it may be recalled, is a non-partisan endowed institution devoted to public service through research in the social sciences.

As a background to the depression there are reviewed the various maladjustments that existed throughout the world and broke through the prosperity surface at the end of the 'twenties. Changing economic conditions during the depression are traced as well as the important readjustments that have taken place. Of particular interest is the discussion of unemployment in relation to potential demands for labor, especially in view of the movement for lessening working hours. Wage readjustments and the probable effect on prices are discussed.

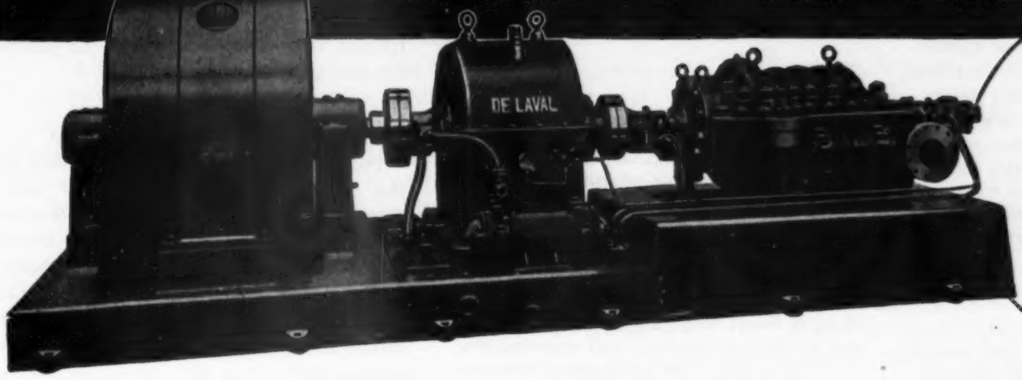
An analysis of the trend of public finance, which was marked by sharp differences from the course pursued in previous depressions, occupies an important place and the extent to which the Government has substituted itself for the private banker is examined in detail.

It is shown that the degree of recovery thus far attained in the United States has been appreciably less than that in many other countries and that, on a per capita basis, industrial output is still 15 per cent below the 1929 level. The per capita income, with allowances for price changes, is less than six-sevenths that of seven years ago and a great increase in production is still necessary.

Among the favorable factors in the present situation are: (1) the abundance of loanable funds at low rates of interest; (2) a satisfactory trend with respect to wage and price relationship; (3) a better balance between agriculture and industry; (4) less uncertainty with respect to monetary and banking policies; (5) the large accumulated deficiency of production as a stimulus to further expansion; and (6) indications of expansion in foreign trade. On the other hand, the unfavorable factors are: (1) the problem of maintaining fiscal stability because of wasteful and unnecessary Federal expenditures; (2) some danger of an inflationary movement; (3) emerging labor policies; (4) ill-conceived industrial legislation; and (5) unstable elements in the international situation. Each of these factors is discussed at some length as showing the necessity for an integrated program to promote further recovery.

The book is one that every executive should read. It contains over 700 pages, size 5×8 in., and is priced at $4.00.

HIGH PRESSURE PUMPS *and* SLOW SPEED MOTORS

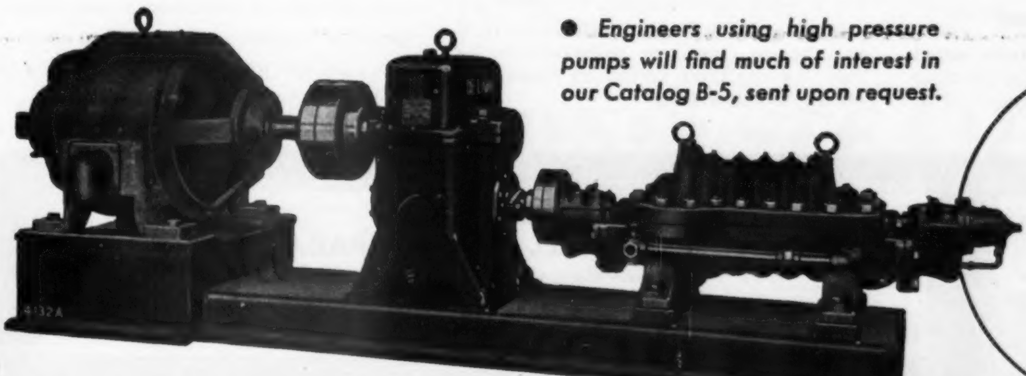


Six-stage pump for de-scaling service in a steel mill; 1000 g.p.m. against 600 lb. per sq. in. at 2300 r.p.m. pump speed; driven through speeding-up gear from 760 r.p.m. motor.

WHERE small or moderate quantities of water are to be pumped against high pressures, the speed most suitable for the pump is quite adaptable to turbine drive, but often higher than the speed of standard electric motors. However, by driving the pump through a DE LAVAL SPEED INCREASING GEAR, as illustrated, excellent pump characteristics are obtained.

The De Laval Multistage Pump with single suction impellers is most compact. Internal leakage is minimized by the fact that the interstage bushings are subject to only a small difference in pressure, while leakage from discharge to suction of each impeller is small, since there is only one joint, instead of the two of a double suction impeller and this joint is sealed by DE LAVAL LABYRINTH WEARING RINGS, which permit only about one-third as much leakage as do plain rings having the same clearance. End thrust is entirely eliminated by a *self-adjusting hydraulic balancing disk,* which does not require close radial clearance for the prevention of leakage.

• *Engineers using high pressure pumps will find much of interest in our Catalog B-5, sent upon request.*



Six-stage boiler feed pump driven at 4000 r.p.m. through helical gear from 1800 r.p.m. D.C. motor; 125 g.p.m. of water at 218° F. against 525 lb. per sq. in.

De Laval *Steam Turbine Co.,* Trenton, N. J.

Manufacturers of Steam Turbines, Centrifugal Pumps, Propeller Pumps, Rotary Displacement Pumps, Centrifugal Blowers and Compressors, Worm Gears, Helical Speed Reducing Gears, Hydraulic Turbines and Flexible Couplings. Sole Licensee of the Bauer-Wach Exhaust Turbine System.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Bent-Tube Boilers

Combustion Engineering Company, Inc., has just issued another of its series of equipment catalogs. This covers its extensive line of C-E bent-tube boilers, many pages being devoted to cross-sections of typical installations of various types, in addition to descriptive matter, photographs of furnace and boiler details, and shop views showing the fabrication of high-pressure, fusion-welded drums from the bending of the plate to the finished product, including X-ray examinations. The catalog is printed in two colors and is attractively illustrated.

Duraloy

The Duraloy Company has just issued a bulletin covering the use of centrifugally-cast chrome-iron and chrome-nickel alloys for such power plant equipment as soot-blower tubes, boiler baffles, dampers, superheater supports and miscellaneous parts where resistance to heat, corrosion and abrasion are important.

Flow Meters

Catalog No. 2004 issued by The Brown Instrument Company describes in simple, non-technical language the operation of Brown flow meters of both the electrical and the mechanical types for indicating, recording and integrating; also, the "Air-o-Line" flow and liquid level controllers. These are discussed in connection with their application to power plants, water works and gas generating service, as well as to general industrial use.

Flue-Gas Analyzer

Catalog N-91-163 has just been issued by Leeds & Northrup Company, dealing with the improved "Micromax" CO_2 recorder. This employs a much simplified cell assembly which conditions the flue-gas sample by saturating rather than drying it. The instrument operates on alternating current and its overall performance is said to be improved over that of the earlier dry-gas models.

Fluid Meters

A 40-page catalog, No. 301, dealing with fluid meters for steam, liquids and gases, is being distributed by the Bailey Meter Company. It illustrates the manner in which any desired combination of indicating, recording and integrating features may be had for the measurement of such fluids and gases under high, low and medium pressures; and explains how the Ledoux Bell flow mechanism operates to record the rate of flow without an external power source. It explains further how auxiliary recorders for pressure and temperature may be incorporated to record on the same chart with the record of flow.

Motorblower

A new catalog on single-stage, Type FS "Motorblowers" has just been issued by Ingersoll-Rand. This bulletin, form 2161-A, features an illustrated discussion of the theory of centrifugal air compression to pressures up to 3 lb, and also contains an illustrated section covering the seven major fields of Motorblower applications.

Pressure Regulator Chart

Davis Regulator Company is distributing a novel chart designed to enable one to make a quick and accurate selection of the proper type of pressure-reducing valve for any given service on steam, gas, oil, air or water lines.

Pumps

Motor-mounted pumps are described in a catalog issued by the De Laval Steam Turbine Company. This term is used to designate a unit consisting of a centrifugal pump mounted directly on the frame of an electric motor to form a compact, self-aligned unit with only one shaft and two bearings. The unit does not require a special foundation or sub-base but can be attached to whatever support is most convenient. It may also be placed on a hand truck or suspended from a sling for portable use. Dimensions and other details are given for pumps of capacities from 5 to 1200 gpm and for heads from 10 to 230 ft. Also, pipe friction tables and instructions for selecting and installing are included.

Stokers

Specifications and engineering data on the C-E Skelly Stoker Unit for small commercial and industrial installations are contained in a new catalog just issued by Combustion Engineering Company, Inc. These stokers are built in the stationary-grate type for coal burning capacities up to 300 lb per hr and in the moving-grate type for capacities up to 2000 lb of coal per hr, for either anthracite or bituminous coal. The latter are built in both the center-retort and the side-retort types with cantilever dump plates, while the former is of the side-retort type. Both employ screw and ram feed.

The catalog contains a table giving the coal per hour, the equivalent steam and hot water radiation supplied and the developed boiler horsepower, stoker and furnace dimensions, setting heights and diagrams of typical settings.

Switchboards

"Modern Switchboard Styling," is the title of a bulletin recently issued by the General Electric Company illustrating a line of control panels, metal-clad gear, cubicles, duplex switchboards and hinged panels all designed on the modern streamline principle with semi-flush mounting of instruments and devices.

Detroit Meeting of the A.S.M.E.

The major features of the Semi-Annual Meeting of the American Society of Mechanical Engineers at Detroit, May 17 to 21, will stress mass production in the Detroit area as typified particularly by the automobile industry. To this end there will be six sessions at which authorities from engineering and industrial fields will discuss the modern techniques employed in mass production, and visits will be made to numerous plants to observe their operations. Among such plants to be visited will be the Plymouth Motor Car Assembly, the Forge Shop and Power Plant of the Chevrolet Motor Company, the Rouge Plant of the Ford Motor Company, the plant of the Budd Wheel Company and the Great Lakes Steel Corporation. Inspection trips will also be made to the Conners Creek Power Plant of the Detroit Edison Company, the Springwells Pumping Station of the Detroit Department of Water Supply, and the Edison Institute's Museum and Greenfield Village.

Following are papers of interest to power engineers:

Tuesday Afternoon, May 18:

- "The Springwells Pumping Station," by W. C. Rudd and B. J. Mullen
- "The Separation and Removal of Cinder and Fly Ash," by Arthur C. Stern
- "Incinerators—Municipal, Industrial and Domestic," by H. F. Hersey

Wednesday Afternoon, May 19:

- "The Prevention of Surface Condenser Tube Failure," by Robert E. Dillon, George C. Eaton and H. Peters
- "The Condensation of Flowing Steam," by Prof. John I. Yellott and C. K. Holland
- "Panel Discussion on Spreader Type Stokers," led by J. F. Barkley

Thursday Afternoon, May 20:

- "The Pooling of Power Resources in a Large Industrial Area," by J. W. Parker and R. E. Greene
- "Analysis and Tests on the Hydraulic Circuits of Surface Condensers," by G. H. Van Hengel

Friday Morning, May 21:

- "Operating Experiences in the Steam and Power Department of the South's First Alkali Plant," by G. P. Avery

At the banquet on Thursday evening, President James H. Herron will give a summary of the week's program and its implications and the principal speaker will be Colonel Williard T. Chevalier. Honorary membership will be conferred upon Alex Dow, President of the Detroit Edison Company and past president of the A. S. M. E. This will be followed by an informal reception and dance.

Headquarters will be at the Hotel Statler.

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